PB-241 904

FEDERAL AIRCRAFT NOISE RESEARCH, DEVELOPMENT, AND DEMONSTRATION PROGRAMS: FY 73 - FY 75

Environmental Protection Agency
Washington, D. C.

March 1975

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TECHNICAL REPORT DATA

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PB 241 904

1. REPORT NO.
600/2-75-003

2.

3.

4. TITLE AND SUBTITLE
Federal Aircraft Noise Research, Development and Demonstration Programs: FY'73 - FY'75

5. REPORT DATE
March, 1975

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
Interagency Aircraft Noise Research Panel

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Interagency Aircraft Noise Research Panel (RD-681)
Office of Research and Development
Environmental Protection Agency
Washington, D. C. 20460

10. PROGRAM ELEMENT NO.
1GB090

11. CONTRACT/GRANT NO.

12. SPONSORING AGENCY NAME AND ADDRESS
Environmental Protection Agency
Office of Research and Development
Washington, D.C. 20460

13. TYPE OF REPORT AND PERIOD COVERED
Final, FY'73 thru FY'75

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

EPA Contact: Eugene E. Berkau, 202-755-0449

16. ABSTRACT

The Interagency Aircraft Noise Research Panel was established by the Environmental Protection Agency to aid EPA in fulfilling its responsibility for coordinating the Federal noise research activities. This report is the first prepared by the Panel and provides an inventory of current and planned Federal aircraft noise RD&D programs. The Federal agencies which sponsor aircraft noise RD&D are the National Aeronautic and Space Administration, the Department of Transportation, the Department of Defense, the National Science Foundation, and the EPA. The report is organized by technical areas with each agency's programs presented under the appropriate technical area. Emphasis is on fiscal years 1974 and 1975, but summary information on fiscal years 1973 and 1976 is also included. The Appendix contains detailed programmatic information as furnished by the Federal agencies on their aircraft related RD&D activities.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Acoustics	Research	Federal noise RD&D	2001
Noise (Sound)	Research projects	Federal noise coordination	1406
Noise reduction	Federal budgets	Research program	1903
Jet aircraft noise		Aircraft	
Jet engine noise		Transportation	
Aerodynamic noise			

18. DISTRIBUTION STATEMENT
Release unlimited

19. SECURITY CLASS *(This Report)*
Unclassified

20. SECURITY CLASS *(This page)*
Unclassified

21. NO. OF PAGES
201

22. PRICE
7.25/2.25

EPA Form 2220-1 (9-73)

PRICES SUBJECT TO CHANGE

Report 600/2-75-003
March 1975

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Prepared by

The Interagency Aircraft Noise Research Panel

Task No. 21AXV
Program Element No. 1GB090

Project Office:
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Office of Research & Development
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Washington, D.C. 20460

Prepared for

U.S. Environmental Protection Agency
Office of Research and Development
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The Interagency Aircraft Noise Research Panel was established by the Environmental Protection Agency to aid EPA in fulfilling its responsibility for coordinating the Federal noise research activities. This report is the first prepared by the Panel and provides an inventory of current and planned Federal aircraft noise RD&D programs. The Federal agencies which sponsor aircraft noise RD&D are the National Aeronautic and Space Administration, the Department of Transportation, the Department of Defense, the National Science Foundation, and the EPA. The report is organized by technical areas with each agency's programs presented under the appropriate technical area. Emphasis is on fiscal years 1974 and 1975, but summary information on fiscal years 1973 and 1976 is also included. The Appendix contains detailed programmatic information as furnished by the Federal agencies on their aircraft related RD&D activities.

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1. INTRODUCTION

Section 4(C)(1) of the Noise Control Act of 1972 requires that the Administrator of the Environmental Protection Agency coordinate research programs of all Federal agencies. To aid the Administrator in fulfilling this requirement, each agency must furnish to the Administrator such information as may be necessary to determine the nature, scope, and results of the noise research programs of the agency. A further requirement under Section 4(C)(3) is that the Administrator publish a report from time to time to describe the status and progress of Federal noise research programs and assess the contributions of these programs to the Federal Government's overall efforts to control noise.

To fulfill these provisions relating to aircraft noise research, the EPA Office of Research and Development has organized an interagency Aircraft Noise Research Panel. The responsibilities of the Panel include collecting programmatic information to develop an inventory of Federal aircraft noise research and providing the expertise to make an assessment of the adequacy of current programs to meet public health and welfare goals relative to noise as specified by the Environmental Protection Agency.

This is an interim report prepared under the cognizance of the Aircraft Noise Research Panel as a first step in carrying out a plan of action to assess aircraft noise related research, development and demonstration (RD&D). The purpose of this report is to provide an inventory of current and planned Federal aircraft noise RD&D programs, and it represents the initial data base upon which the assessment will be made.

The report is organized by technical areas with each agency's programs presented under the appropriate technical areas. Sections 1 through 9 provide an overview of objectives and funding for the programs with emphasis on fiscal years (FY) 1974 and 1975. Summary information on past funding for FY 1973 and planned obligations for FY 1976 are also included. The Appendix contains detailed programmatic information as furnished by the Federal agencies on their aircraft noise related RD&D activities.

In the future, the Aircraft Noise Research Panel will carry out the assessment phase of its responsibilities. To accomplish this objective the Panel will:

1. Review the public health and welfare goals and objectives relating to noise as developed by the Environmental Protection Agency;

2. Establish appropriate Working Groups for specific technology areas calling on the expertise available in Federal agencies engaged in aircraft RD&D;

3. Identify specific requirements and need for detailed review of Federal programs and analyze industry independent research and development programs;

4. Coordinate Working Group activity and integrate findings of the Working Groups relative to the adequacy of ongoing programs;

5. Prepare a summary report that specifies the extent to which current programs can meet the EPA public health and welfare goals and objectives relative to noise and make recommendations on what should be done where the assessment indicates that the schedule for meeting EPA goals and objectives cannot be accomplished with current programs and plans.

2. SUMMARY

The overall Federal activity in aircraft noise related research, development and demonstration is summarized in Table 2.1. Table 2.1 shows the technical areas under investigation, the Federal agencies with a significant program in each technical area and noise relevant funding data for fiscal years 1973 through 1976. Funding data for FY 1975 and FY 1976 are based on planned obligations.

It is noted from Table 2.1, that a significant amount of total funding in FY 73 and FY 74 is associated with studies to reduce noise of the current commercial fleet and is shown under subsonic conventional takeoff and landing (CTOL) aircraft. Several study categories related to noise of existing commercial aircraft are presented in Table 2.2. The programs included in Table 2.2 involve operational procedures for reduced noise exposure, technology development, and demonstration to support decision making on the question of retrofit of the existing commercial fleet and demonstration of advanced technology for nacelle design for application on modern wide-body transports. The status of some of the NASA and DOT/FAA activities identified in Table 2.2 were reviewed before the United States House of Representatives Subcommittee on Aeronautics and Space Technology in July 1974. The testimonies presented by NASA and DOT/FAA are included in the Appendix of this report.

The ongoing programs to provide the research and technology base necessary to design more quiet future generation aircraft are summarized in Table 2.3, page 5. Major areas of investigation are propulsion system noise, materials, and nonpropulsive noise (airframe aerodynamic noise). A parallel decrease of propulsion system noise and airframe noise is required to reduce approach noise of future aircraft below FAR-36 minus 10 dB (see References 1 and 2, Section 10, for detailed technical treatment of this point).

Programs to develop acceptably quiet commercial powered lift aircraft to reduce congestion around major cities are summarized in Table 2.4. The technical objectives of these programs are given in Section 4, and detailed program planning is included in the Appendix. A technical treatment of progress and prospects for powered lift aircraft is provided in Reference 1, Section 10.

Table 2.5 summarizes program activity and funding for rotorcraft and vertical takeoff and landing (VTOL) aircraft. These programs, conducted by NASA, have civil and military applications. Noise relevant technology development for application to supersonic cruise aircraft is given in Table 2.6. These programs are basic and deal with propulsion, aerodynamics and sonic boom.

Table 2.1 SUMMARY OF FUNDING BY TECHNICAL AREA, AGENCY, AND FISCAL YEAR

Funding in Thousands of Dollars

Technical Area	Agency	FY 73	FY 74	FY 75	FY 76
Basic Research and Technology	NASA	10,765(1)	14,149	13,840	14,269
	DOT	2,830	785	1,282	1,760
	DOD	1,784	1,752	793	1,112
	Total	15,379	16,686	15,915	17,141
Powered Lift Aircraft Noise Technology	NASA	4,406(1)	2,082	2,977	2,952
	DOT	241	-	-	-
	Total	4,647	2,082	2,977	2,952
Rotorcraft/VTOL Noise Technology	NASA	- (2)	1,774	2,284	2,294
	DOD	267	534	675	275
	Total	267	2,303	2,959	2,569
Air Transportation Systems Studies	NASA	255	428	248	227
	EPA	- (4)	404	-	-
	Total	255	832	248	227
Supersonic Cruise Aircraft Noise Technology	NASA	2,070(1,3)	2,085	1,490	1,730
	DOT	316	299	100	-
	Total	2,386	2,385	1,590	1,730
Subsonic Conventional Takeoff and Landing Aircraft Noise Programs	NASA	27,704(1,6)	25,204	6,017	2,703
	DOT	8,176	1,899	900	-
	Total	35,880	27,103	6,917	2,703
General Aviation Noise Technology	NASA	80(1)	355	448	996
GRAND TOTAL		58,894	51,751	31,054	28,318

1. The NASA funding data included in this table for FY 73 are based on information supplied to EPA by NASA in December, 1973. The content of the breakouts by research area is not exactly the same as those for other fiscal years listed.

2. FY 73 funding included in Powered Lift Aircraft Noise Technology.

3. Some program activity included here that is listed under Basic Research and Technology for other fiscal years.

4. EPA FY 74 total includes some funds committed in FY 73.

5. See Section 11 for an explanation of acronyms, abbreviations, and definition of noise relevant program costs.

6. For FY 73, $1090K of the funds listed were for subsonic engine and nacelle technology-Quiet Engine I.

Table 2.2. FUNDING SUMMARY FOR SUBSONIC CTOL AIRCRAFT NOISE PROGRAMS

Area	Agency	Funding Distribution, Thousands of Dollars		
		FY 74	FY 75	FY 76
Noise Reduction Flight Procedures Experiments	NASA	3,600	1,380	-
Terminal Configured Vehicle Operating Systems Experiments	NASA	271	1,563	1,613
REFAN Program	NASA	20,803	2,514	-
Advanced Acoustic Composite Nacelle Program	NASA	530	560	1,090
Source Noise Reduction	DOT/FAA	1,899	900	-
	GRAND TOTAL	27,103	6,917	2,703

Table 2.3. FUNDING SUMMARY FOR BASIC RESEARCH AND TECHNOLOGY PROGRAMS

Area	Agency	Funding Distribution, Thousands of Dollars		
		FY 74	FY 75	FY 76
Propulsion Noise Reduction	NASA	13,348	12,194	12,490
	DOT/ONA*	750	1,232	1,710
	DOD	563	271	400
	Total	14,661	13,697	14,600
Propulsion System Integration	NASA	801	1,646	1,779
Nonpropulsive Noise	DOD	272	75	125
	Total	1,073	1,721	1,904
Human Response**	NASA	(1,154)	(1,200)	(1,458)
Materials and Sound Propagation	DOT/ONA	35	50	50
	DOD	917	447	587
	Total	952	497	637
	GRAND TOTAL	16,686	15,915	17,141

*DOT/FAA funding included in Table 2.2

**NASA allocations for Human Response studies are shown here for informational purposes only. These resources are accounted for in the Federal noise effects research fiscal data. (Reference 3)

Table 2.4. FUNDING SUMMARY FOR POWERED LIFT AIRCRAFT NOISE TECHNOLOGY

Area	Agency	Funding Distribution, Thousands of Dollars		
		FY 74	FY 75	FY 76
Advanced Powered Lift Aircraft	NASA	310	1,480	1,470
Augmentor Wing Flight Experiment	NASA	160	-	-
Quiet Clean Short Haul Experimental Engine (QCSEE)	NASA	167	840	825
Quiet Propulsive Lift Research Aircraft	NASA	1,310	-	-
STOL Operating Systems Experiments	NASA	135	657	657
GRAND TOTAL		2,082	2,977	2,952

Table 2.5. FUNDING SUMMARY FOR ROTORCRAFT/VTOL NOISE TECHNOLOGY

Area	Agency	Funding Distribution, Thousands of Dollars		
		FY 74	FY 75	FY 76
Advanced Rotorcraft Aerodynamic Technology	NASA	920	1,045	1,040
	DOD	34	-	-
	Total	954	1,045	1,040
Advanced VTOL Aircraft Aerodynamic Technology	NASA (Total)	80	150	160
Tilt Rotor Research Aircraft Program	NASA (Total)	274	-	-
Rotor Systems Research Aircraft	NASA	500	-	-
	DOD	500	675	275
	Total	1,000	675	275
Rotor Systems for RSRA	NASA (Total)	-	465	470
VTOL Operating Systems Experiments	NASA (Total)	-	624	624
GRAND TOTAL		2,308	2,959	2,569

Table 2.6. FUNDING SUMMARY FOR SUPERSONIC CRUISE AIRCRAFT NOISE TECHNOLOGY

Area	Agency	Funding Distribution, Thousands of Dollars		
		FY 74	FY 75	FY 76
Propulsion Technology	NASA	1,422	1,233	1,360
Aerodynamic Performance	NASA	664	257	370
Source and Operational Sonic Boom Reduction	DOT/FAA	299	100	-
	GRAND TOTAL	2,385	1,590	1,730

A more detailed treatment of the Federal noise relevant RD&D summarized in Tables 2.1 to 2.6 is given in subsequent sections of this report. Program planning and several status reviews (July 1973) on the potential of reducing noise of the current commercial fleet are included in the Appendix.

3. SUBSONIC CONVENTIONAL TAKEOFF AND LANDING AIRCRAFT NOISE PROGRAMS

Noise relevant programs relating to subsonic conventional takeoff and landing aircraft technology are listed in this section. These programs have application to the existing commercial fleet and the newer wide-body aircraft designs.

National Aeronautics and Space Administration

The status of NASA programs noted here was reviewed in testimony before the United States House of Representatives Subcommittee on Aeronautics and Space Technology in July 1974. The brief technical descriptions of programs that follow can be understood in proper context by referring directly to that testimony which is included in the Appendix.

- Noise reduction flight procedures experiments. To reduce 90 EPNdB approach noise footprint by at least 60% through scheduled airlines' demonstrations of avionic systems for noise abatement flight procedures.
- Terminal configured vehicles operating systems experiments. To identify and provide proven technology and operating techniques for advanced CTOL and RTOL aircraft for reducing approach and landing accidents, reducing weather minima, increasing air traffic controller productivity and airport and airway capacity, saving fuel by more efficient terminal area operations, and reducing noise by operational procedures during the 1976-2000 time period.
- REFAN Program. To provide the technology to obtain a 75 percent reduction in the noise footprint area of JT8D-Powered Aircraft (727, 737, and DC-9) which account for over 60 percent of domestic fleet operations.
- Advanced acoustic composite nacelle flight program. To demonstrate on a modern wide-body transport in airline operation the application of advanced interwoven acoustic absorbent and composite structural materials to an engine which will:
  - Reduce the noise footprint area of future production wide-body transport aircraft by 30 percent with no increase in aircraft weight or fuel consumption or

alternately reduce aircraft weight and fuel consumption with no increase in noise.

- Together with advanced technology engines, reduce the 90 EPNdB noise footprint area of advanced technology transport aircraft to 5.2 square kilometers (2 square miles) with no increase in aircraft weight or fuel consumption resulting from the nacelle or alternately reduce aircraft weight and fuel consumption together with some noise reduction.

Table 3.1 is a summary of noise relevant funding for the subsonic conventional takeoff and landing aircraft noise program. Listed in the table are a descriptive title of the program and gross RD&D and manpower costs for FY's 1974 through 1976. The Appendix contains more detailed program descriptions on all programs.

Department of Transportation-Federal Aviation Administration

DOT/FAA has several subsonic conventional takeoff and landing aircraft noise programs under the overall program of source noise reduction. The objective of this program is to develop a noise source prediction capability for all categories of aircraft. Projects under the source noise prediction and reduction program and their objectives are:

- Core engine noise control. To provide theoretical and experimental data to assist the designers in developing future aircraft capable of conforming to lower noise levels than are now required by FAR Part 36. This program would more properly be listed in Section 4 but is presented here since it cannot be easily separated from the schedule and cost data of other programs presented in this section.

- Prediction of aircraft configuration effects. To study the feasibility of use of aircraft configuration and engine placement to reduce noise propagation to the ground plus development of prediction procedures for configurations of practical interest.

- General aviation aircraft. To survey and define the noise characteristics of all general aviation aircraft plus development of suitable noise prediction capabilities.

- Retrofit feasibility. To provide test data to assist in determining whether certain classes of turbofan propelled airplanes in the current fleet can be modified for meaningful noise reduction in a feasible manner. The results of this

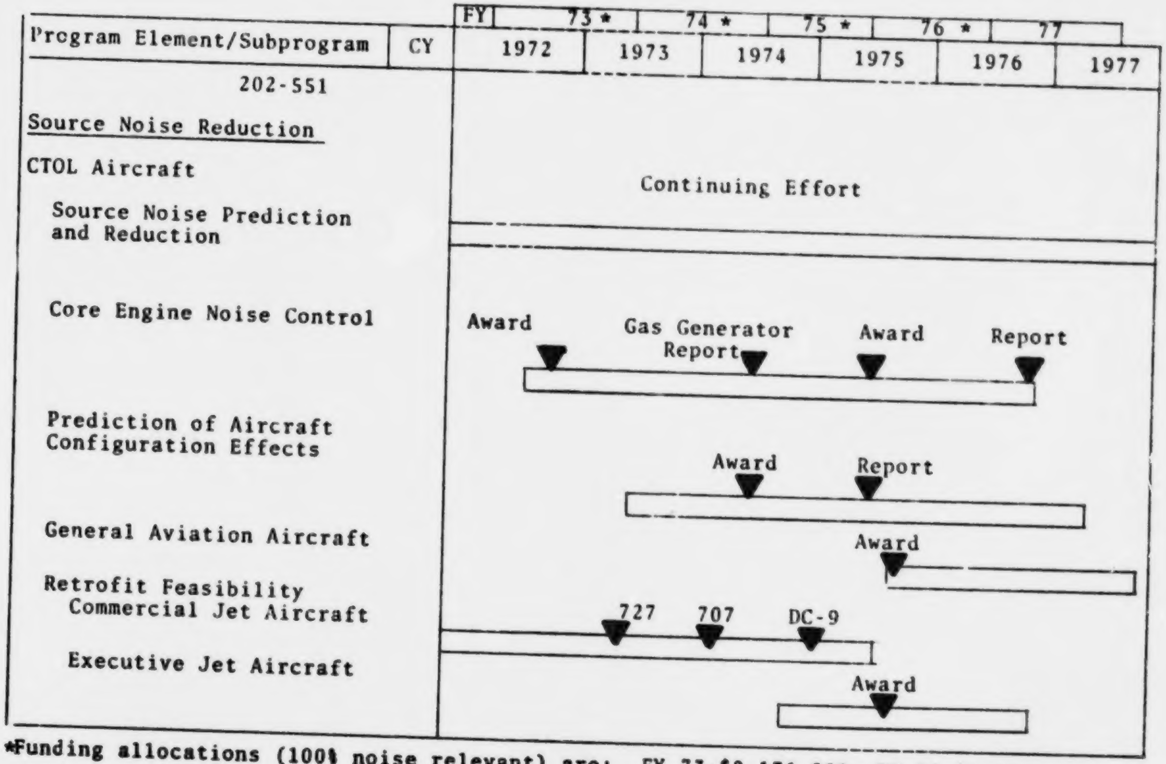
Table 3.1. NASA NOISE RELEVANT SUBSONIC CTOL AIRCRAFT PROGRAMS
NOISE RELEVANT PROGRAM COSTS
(Thousands of Dollars)

Descriptive Title	FY 1974 Gross R&D	FY 1974 Manpower Costs	FY 1974 Total	FY 1975 Gross R&D	FY 1975 Manpower Costs	FY 1975 Total	FY 1976 Gross R&D	FY 1976 Manpower Costs	FY 1976 Total
Noise Reduction Flight Procedure Experiments	3140	460	3600	1050	330	1380	-	-	-
Terminal Configured Vehicle System Experiments	214	57	271	1450	113	1563	1500	113	1613
REFAN Program	19545	1258	20803	1000	1514	2514	-	-	-
Advanced Acoustic Composite Nacelle Program	500	30	530	500	60	560	1000	90	1090
TOTALS	23399	1805	25204	4000	2017	6017	2500	203	2703

programmatic activity were reviewed before the United States House of Representatives Subcommittee on Aeronautics and Space Technology July 1974. That testimony is included in the Appendix.

Table 3.2 gives the schedule and funding for source noise reduction programs. The Appendix contains additional information on the direction and status of these projects.

Table 3.2. DOT/FAA AIRCRAFT NOISE ABATEMENT--SOURCE NOISE REDUCTION
Program Schedule (July 1, 1974)



*Funding allocations (100% noise relevant) are: FY 73-$8,176,000; FY 74-$1,899,000; FY 75-$900,000; FY 76-No Data.

4. BASIC RESEARCH AND TECHNOLOGY

Strict guidelines have not been employed in listing various agency programs under the category of Basic Research and Technology. In general, the results of programs presented in this section have a broader range of application and are more fundamentally oriented than programs listed in other sections.

National Aeronautics and Space Administration

Descriptive titles and specific objectives for each noise relevant study being conducted by NASA are:

- Propulsion noise reduction. To provide data and a technology base for reducing aircraft propulsion noise with minimum weight, performance, and economic penalties.
- Nonpropulsive noise. To understand and minimize, by aerodynamic means, the undesirable effects of airframe noise.
- Human Response. To define and quantify those properties of aircraft noise exposure that are responsible for causing negative individual and community response to air transportation systems.

Funding data for programs included with each study category are shown in Table 4.1. The Appendix contains objective documentation for the programs listed in Table 4.1.

Department of Transportation-Office of Noise Abatement

Studies relevant to aircraft noise reduction are sponsored by the Office of Noise Abatement within the Office for Systems Development and Technology and by the Federal Aviation Administration within DOT. While some FAA studies may be appropriately considered here, a consistent treatment of cost data requires their listing elsewhere. For this reason, only the DOT/ONA programs are considered under Basic Research and Technology.

DOT/ONA sponsors one program in aircraft noise reduction. This program is directed toward understanding, modeling, and suppressing jet noise. The studies included in the program are conducted under contract and through interagency agreement. The title, contracting organization, and funding data for each project are shown in Table 4.2. Detailed descriptions of each project are included in the Appendix.

Table 4.1 NASA NOISE RELEVANT BASIC RESEARCH AND TECHNOLOGY
NOISE RELEVANT PROGRAM COSTS
(Thousands of Dollars)

Descriptive Title	FY 1974			FY 1975			FY 1976		
	Gross R&D	Manpower Costs	Total	Gross R&D	Manpower Costs	Total	Gross R&D	Manpower Costs	Total
Propulsion Noise Reduction									
Basic Noise Research	2108	1886	3994	1300	2161	3461	1500	2200	3700
Noise Technology and Prediction	3073	6281	9354	4450	4283	8733	4330	4460	8790
Nonpropulsive Noise									
Airframe Aerodynamic Noise	408	393	801	900	746	1646	1000	779	1779
Human Response[1]									
Acceptance of Aircraft Operations	(796)	(358)	(1154)	(842)	(358)	(1200)	(1100)	(358)	(1458)
GRAND TOTALS	5589	8560	14,149	6650	7190	13,840	6830	7439	14,269

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[1] The fiscal data for NASA's Human Response studies are accounted for in the Federal noise effects research resource allocations and shown here for informational purposes only. (Reference 3)

Table 4.2 DOT/ONA JET NOISE RESEARCH PROGRAM

Project Title	Contracting Organization	Contract Number	Program Manager	Planned Obligations (Thousands of Dollars)			
				FY73	FY74	FY75	FY76
Modeling Jet Noise	USC	DOT-OS-0000-2	G.Banerian	75	75	50	50
Noise Reduction from Supersonic Jet Flow with Co-Axial Jets	Syracuse	DOT-OS-20094	G.Banerian	75	75	75	75
Jet Combustion Noise	Cal. Tech.	DOT-OS-20197	G.Banerian	147	50	50	50
Effects of Nonlinearity on Jet Noise Propulsion	UT	DOT-OS-4117	G.Banerian	0	20	0	0
On the Origin of Combustion Generated Noise	NCSU	DOT-OS-40056	G.Banerian	0	25	30	30
High Velocity Jet Noise Source Location and Reduction Program	GE	DOT-OS-30034	G.Banerian	2500	500	1000	1500
Interagency Symposium: Transportation Noise	-	-	G.Banerian	0	5	5	5
Acoustic Material Research	MIT	DOT-OS-30011	G. Banerian	33	35	50	50
Suppression of Multiple Pure Tones	VPI	DOT-OS-50047	G. Banerian	0	0	22	0
GRAND TOTALS				2830	785	1282	1760

Department of Defense

DOD has projects in several research categories. General areas of research are summarized below:

Propulsion Noise Reduction

- Jet Exhaust noise programs. To develop the technology base necessary to significantly reduce aircraft propulsion system noise with minimum associated performance and weight penalties.

- Rotating machinery noise programs. To define the fundamental physical mechanisms by which combustion affects the general sound field surrounding an engine, to aid in providing design guidelines and techniques for modifying the combustion process for minimum noise levels, developing effective combustor noise suppression devices, and establishing criteria for engine design, development and control.

- Duct acoustics and suppression programs. To develop computer routines to predict the effect of duct linings on noise propagation and to optimize a given duct configuration for maximum noise reduction.

- Propeller noise programs. To formulate and computer program a comprehensive unified aerodynamic acoustic source theory and to reduce propeller noise through utilizing unique propeller designs based on noise source theory analysis.

Structural Response Programs

Objectives of projects in this area are:

- To investigate the effects of high intensity sound on aircraft structures.

- To study the effects of high lift device noise on aircraft structures and the community environment.

- To dampen noise in helicopters.

Sound Propagation Programs

Objectives of projects in this area are:

- To analyze the generation and propagation of multiple turbojet exhaust noise sources.

- To analyze the aerodynamic generation of noise, propagation, and detectability of unpowered aircraft.

Airflow Surface Interaction Programs

Objectives of the projects in this area are:

- To investigate the reduction of noise by liquid vaporization.
- To investigate the dynamics of vortices and shock waves in nonuniform media.
- To investigate the areas of boundary layer flows.

Table 4.3 is a compilation of the DOD funding distribution on Basic Research and Technology Programs. The Appendix contains a brief description of each project.

Table 4.3 DOD AIRCRAFT NOISE RESEARCH PROGRAMS[1]

Descriptive Title[2]	Agency	Funding Level, Thousands of Dollars FY 73	FY 74	FY 75[3]	FY 76[3]
Propulsion Noise Reduction					
• Jet Exhausts	Air Force	447	204	122	250
• Rotating Machinery	Air Force Army, Navy	297	288	75	85
• Duct Acoustics and Suppression	Air Force Army	10	45	65	65
• Propeller Noise	Air Force	26	26	9	-
Structural Response Programs	Air Force	178	335	302	340
Sound Propagation Programs	Air Force	580	582	145	247
Airflow Surface Interaction	Navy	246	272	-	-
	Air Force	-	-	75	125
GRAND TOTALS		1,784	1,752	793	1,112

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[1] All programs are 100% noise relevant.
[2] See Appendix for detailed project listing and description of projects
[3] Data on FY 75 and FY 76 are incomplete.

5. POWERED LIFT AIRCRAFT NOISE TECHNOLOGY

Noise technology activities associated with power-generated lift aircraft technology programs are considered in this section. Coverage is restricted to STOL/RTOL aircraft for short-haul applications to meet civil and military transport needs.

National Aeronautics and Space Administration

The major study categories related to powered lift aircraft with noise relevancy being conducted by NASA are as follows:

- Advanced powered lift aircraft aerodynamic technology. To develop the aerodynamics and systems technology needed to attain the integrated aerodynamic performance, noise, stability, control, and handling qualities characteristics required for viable powered lift in civil and military aircraft designs.

- C-8 augmentor wing flight experiment. To validate in flight the augmentor wing powered lift concept developed in laboratory programs as a practical means for providing STOL capability. To assess in flight the handling qualities of this type of aircraft. To provide a versatile representative powered lift aircraft for assessment of navigation and control systems requirements for safe terminal area operation.

- Quiet, clean, short-haul experimental engine (QCSEE). To design, build, and test experimental engines to consolidate and demonstrate the technology needed for very quiet, clean, and efficient propulsion system for economically viable and environmentally acceptable powered lift short-haul aircraft.

- Quiet propulsive lift technology (Advanced medium STOL (AMST) prototype aircraft). To obtain, through participation in the Air Force AMST prototype programs, propulsive lift flight research data on a straight-wing externally blown flap configuration at lift coefficients up to about 3.5.

- STOL operating systems experiments. To establish a technology base upon which operational STOL short-haul systems can be based with confidence in the 1978-2000 time period. To demonstrate operating systems technology, operating procedures, and guidance, navigation, and control concepts for high-density terminal area operation.

Funding data for these programs are given in Table 5.1. Specific technology goals, milestones, and technical and management approach are given in the Appendix for each NASA study category presented in Table 5.1.

Department of Transportation-Federal Aviation Administration

The FAA participates with NASA in program activity related to powered lift aircraft technology as noted previously in Table 5.1. Additionally, the FAA conducts a program on V/STOL aircraft. A descriptive title and broad statement of objectives for this program follows:

- V/STOL aircraft - noise source reduction. To identify, evaluate, and control component noise sources inherent in V/STOL systems including studies of jet propulsion and rotary systems and noise prediction techniques.

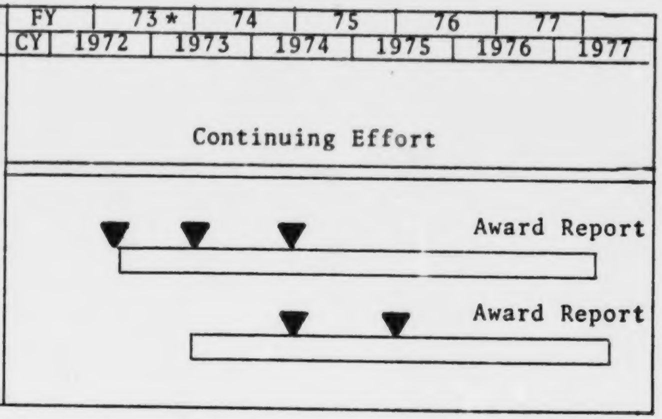
Table 5.2 gives the FAA identification number for the V/STOL aircraft noise program, the major subprogram titles, the program schedule, and funding data as of July 1, 1974. For FY 1974 and FY 1975 contract funding is included with other programs and is therefore listed elsewhere in this report. A more detailed description of this program is given in the Appendix.

Table 5.1 NASA NOISE RELEVANT POWERED LIFT AIRCRAFT TECHNOLOGY
NOISE RELEVANT PROGRAM COSTS
(Thousands of Dollars)

Descriptive Title	FY 1974 Gross R&D	FY 1974 Manpower Costs	FY 1974 Total	FY 1975 Gross R&D	FY 1975 Manpower Costs	FY 1975 Total	FY 1976 Gross R&D	FY 1976 Manpower Costs	FY 1976 Total
Advanced Powered Lift Aircraft Aerodynamic Technology	140	170	310	900	580	1480	900	570	1470
C-8 Augmentor Wing Flight Experiment	100	60	160	-	-	-	-	-	-
Quiet, Clean Short-Haul Experimental Engine (QCSEE)	137	30	167	800	40	840	800	25	825
Quiet Propulsive Lift Technology	1100	210	1310	-	-	-	-	-	-
STOL Operating Systems Experiments	107	28	135	600	57	657	600	57	657
TOTALS	1584	498	2082	2300	677	2977	2300	652	2952

Table 5.2. DOT/FAA PROGRAM SCHEDULE RELEVANT TO POWERED LIFT AIRCRAFT NOISE TECHNOLOGY

Program Element/Subprogram	Program Element Number
V/STOL Aircraft	202-590
Source Noise Prediction and Reduction	
Jet Propulsors	
Rotary Propulsors	



*Funding for FY 1973: $241,000 - 100% noise relevant.

6. ROTORCRAFT/VTOL NOISE TECHNOLOGY

This section considers noise relevant studies associated with technology programs for aircraft with rotor induced lift and advanced VTOL lift concepts. It deals primarily with VTOL aircraft for civil and military applications.

National Aeronautics and Space Administration

The noise relevant rotorcraft technology programs and statements of objectives are as follows:

- Advanced rotorcraft aerodynamic technology. To determine and improve the performance, dynamic loads, noise, control, stability, vibration, and handling qualities characteristics of helicopter rotors and rotorcraft configurations in order to permit the development of rotorcraft having substantially greater mission and cost effectiveness than current (1973) operational vehicles in military and civil usage.

- Advanced VTOL aircraft aerodynamic technology. To provide the technology required to enable the development of viable military and civil aircraft having effective VTOL capability together with speed, range, operating cost, and mission/operational capabilities, approaching those of 1973 operational medium range military and civil CTOL aircraft. This requires the development of a thorough knowledge and understanding of the aerodynamic performance, noise, control, stability characteristics, and piloting qualities peculiar to VTOL system concepts.

- Tilt rotor research aircraft. To demonstrate advanced rotorcraft technology for military and civil VTOL vehicles having twice the cruise speed of the helicopter while retaining its efficient hover capability.

- Rotor systems research aircraft. To provide a unique flight test capability in 1976 for advanced rotor research on a wide variety of promising new rotor concepts. To expedite improved rotorcraft research through the use of a specially designed flight test vehicle.

- Rotor systems for rotor systems research aircraft (RSRA). To select, acquire, and evaluate on the Rotor Systems Research Aircraft (RSRA), under joint development by the Army and NASA, three practical advanced rotor systems concepts. To demonstrate through tests of these concepts in the real flight environment the integrated performance, dynamics, and acoustics technology improvements achievable.

- VTOL operating systems experiments. To establish a technology base leading to improved operational capability, improved VTOL operating efficiency, and decreased environmental impact. To support military technology requirements for assuring VTOL operational capability with a wide variety of landing sites and under reduced visibility conditions.

Table 6.1 provides a funding summary of the Rotorcraft/VTOL aircraft technology studies with noise relevance being conducted by NASA. Specific technology goals, milestones, and technical approach are included in the Appendix for each of the studies listed in Table 6.1.

Department of Defense

DOD Rotorcraft/VTOL noise technology programs and their objectives are:

- Tip vortex effects on rotary-wing aerodynamics. To significantly reduce undesirable rotor blade noise signatures and alleviate the blade-tip vortex interaction problem.

- Glare and noise reduction of helicopter rotor blades. To develop various materials and compositions capable of reducing the glint, glare, and noise from helicopter rotor blades without impairing lift or increasing weight or drag.

- Unsteady aerodynamics of blade-vortex interaction. To study the unsteady aerodynamic mechanisms responsible for helicopter noise.

- Investigation of noise generation on a hovering rotor. To define the noise field generated by a rotor.

- Analytical studies of helicopter rotor broadband noise generation. To establish a closed form solution for predicting the broadband noise intensity radiated by helicopter rotors.

- Studies in low speed flight. To investigate problems associated with low speed flight of helicopters.

- Systems studies of helicopter noise requirements. To establish a new methodology for systems analysis which includes noise criteria and to develop a new wind tunnel facility for making

Table 6.1 NASA NOISE RELEVANT ROTORCRAFT/VTOL TECHNOLOGY PROGRAMS
NOISE RELEVANT PROGRAM COSTS
(Thousands of Dollars)

	FY 1974			FY 1975			FY 1976		
Descriptive Title	Gross R&D	Manpower Costs	Total	Gross R&D	Manpower Costs	Total	Gross R&D	Manpower Costs	Total
Advanced Rotorcraft Aerodynamics Technology									
Helicopter Aerodynamics	265	180	445	205	95	300	200	100	300
Tilt Rotor Aerodynamics	20	10	30	70	40	110	70	40	110
Civil Helicopter Tech.	220	50	270	280	55	335	280	50	330
Rotor Systems Technology	140	35	175	-	-	-	-	-	-
Rotor Acoustics and Aeroelasticity	-	-	-	195	105	300	200	100	300
Advanced VTOL Aircraft Aerodynamic Technology	50	30	80	100	50	150	100	60	160
Tilt Rotor Research Aircraft Program	250	24	274	-	-	-	-	-	-
Rotor Systems Research Aircraft	500	-	500	-	-	-	-	-	-
Rotor Systems for RSRA	-	-	-	400	65	465	400	70	470
VTOL Operation Systems Experiments	-	-	-	400	224	624	400	224	624
TOTALS	1445	329	1774	1650	634	2284	1650	644	2294

useful noise measurements on V/STOL aircraft types.

- Tilt rotor research aircraft. To supplement funding of program conducted by NASA in cooperation with the Air Force.
- Rotor systems research aircraft. To supplement funding of program being conducted by NASA in cooperation with the Air Force.

Funding levels for DOD Rotorcraft Noise Technology Programs are: $267,000 for FY 1973, $534,000 for FY 1974, $675,000 for FY 1975, and $275,000 in FY 1976. The Appendix contains brief descriptions of DOD programs listed here.

7. SUPERSONIC CRUISE AIRCRAFT NOISE TECHNOLOGY

Programs with noise relevancy that are directed toward providing a technology base for future generation aircraft with supersonic cruise capability are presented in this section. It is noted that many of the programs listed under Section 4, Basic Research and Technology, have direct application to supersonic cruise aircraft.

National Aeronautics and Space Administration

NASA has two programs dedicated to supersonic cruise aircraft (SCAR) technology with noise relevancy:

- SCAR propulsion technology. To establish an expanded supersonic propulsion technology base in parallel with the expansion of other supersonic disciplinary technologies which will permit the reduction of noise in takeoff and landing to levels less than the Douglas DC-10 and Lockheed 1011; reduce fuel consumption rates which can make supersonic cruise aircraft significantly more efficient; and nitric oxide emissions at high altitudes that are greatly reduced from levels possible with today's technology.

- SCAR aerodynamic performance technology. To establish an expanded supersonic aerodynamics technology base in parallel with the expansion of other supersonic disciplinary technologies which will permit improvements in L/D, reductions in sonic boom, and the translation of technical advances into integrated aircraft systems.

Table 7.1 is a funding summary for the supersonic cruise aircraft noise technology programs. Each program and noise related project is listed. More detailed program descriptions are given in the Appendix.

Department of Transportation-Federal Aviation Administration

The FAA is conducting two programs relative to supersonic cruise aircraft noise technology. They are:

- Source sonic boom reduction. This is an effort to develop a definition of the air and ground system requirements for successful threshold mach number operation.

Table 7.1 NASA NOISE RELEVANT SUPERSONIC CRUISE AIRCRAFT TECHNOLOGY STUDIES
NOISE RELEVANT PROGRAM COSTS
(Thousands of Dollars)

Descriptive Titles	FY 1974			FY 1975			FY 1976		
	Gross R&D	Manpower Costs	Total	Gross R&D	Manpower Costs	Total	Gross R&D	Manpower Costs	Total
Propulsion Technology									
Propulsion Noise Reduction Technology	618	330	948	843	390	1233	1000	360	1360
Experimental Engine Cycle Studies	410	18	428	-	-	-	-	-	-
Low Noise Engine Unique Components	46	-	46	-	-	-	-	-	-
Aerodynamic Performance Technology									
Integration Studies	137	90	227	-	-	-	-	-	-
Theory	-	30	30	-	-	-	-	-	-
Sonic Boom	137	270	407	167	90	257	280	90	370
TOTALS	1348	738	2086	1010	480	1490	1280	450	1730

- Operational sonic boom reduction. This effort is to provide prototype, digital, lightweight, inexpensive sonic boom recorders and to obtain real time atmospheric data for use in long-range threshold mach number operational feasibility studies.

Table 7.2 shows the program schedule for the source sonic boom reduction and operational sonic boom reduction programs. The schedule has been updated to indicate milestones and targets as of July 1, 1974.

Table 7.2. DOT/FAA SOURCE SONIC BOOM REDUCTION, OPERATIONAL SONIC BOOM REDUCTION PROGRAM SCHEDULE (JULY 1, 1974)

Program Element/Subprogram	FY	73*	74*	75*	76*	77
	CY 1972	1973	1974	1975	1976	1977
202-554 **Source Sonic Boom Reduction** Supersonic boomless flight research	Phase I RFP	Phase II Award	Phase III Final Report	Trans. Flight RFP	Phase IV System Award	Final Report
Ft. Worth F-111/F-8 operational research boomless flight; other operational programs.	Award	Phase I Report	Phase II Report	Phase III Report		Final Report
Operational Sonic Boom Reduction Sonic boom signature prototype digital recording system. Operation, maintenance and data collection during operational programs	Award	Delivery	Field Test	2 Prototypes recorders		

*Funding allocations (100% noise relevant) are: FY 73 - $316,000; FY 74 - $299,000; FY 75 - $100,000; FY 76 - no funds scheduled

8. AIR TRANSPORTATION SYSTEMS STUDIES

Studies considered in this section are concerned with the interrelation of future air transportation needs, technology requirements, socioeconomic and environmental factors, and aircraft/airport interface.

National Aeronautics and Space Administration

Systems studies being conducted by NASA that have significant noise relevance are:

- Quiet propulsive lift transport technology systems studies. To identify, through aircraft definition and transportation systems studies, the problem areas, configurations and technology for emphasis in future quiet propulsive lift technology programs, including flight research.

- Short-haul transportation systems analysis. To develop a sound technological base for future decisions relating to the design, development, and operation of short-haul transportation systems; to examine the relationships between short-haul technology and short-haul economics, markets, and implementation; to identify potential viable short-haul airplane concepts and their design and performance criteria for practical short-haul transportation systems including consideration of market, economic, and environmental factors.

- Analysis of future civil air transportation systems and concepts. To identify promising aeronautical systems, determine optimum characteristics, and define technology requirements and costs associated with such systems. Studies include general aviation aircraft, CTOL, STOL, and VTOL transports, advanced subsonic transonic transport aircraft, and advanced supersonic transports.

- High transonic speed transport (HiTST) system study. To provide detailed configuration definitions of a high transonic speed transport concept with design studies to include fatigue and flutter characteristics of composite structures, low speed stability, and control of yawed wing for emergency maneuvers, and new engine technology application for reduced noise.

- Subsonic/Transonic C/RTOL transport technology systems and design studies. To make technology advances available for superior subsonic C/RTOL transport aircraft to satisfy anticipated requirements in the 1980's; to determine the feasibility of utilizing aircraft fuels other than JP fuel for subsonic cargo and passenger aircraft; to investigate new approaches to providing more economical subsonic transport of liquid and solid cargo in anticipation of the need for increased air transport of cargo.

- Subsonic/Sonic CTOL transport technology propulsion studies. To study the application of advanced technology to the improvement of future commercial transport aircraft including consideration of economic factors involving parameters such as aircraft drag, propulsion efficiency, cost, and propulsion system noise and exhaust emissions.

Table 8.1 provides a funding summary of the air transportation systems studies being conducted by NASA and discussed in the preceding paragraphs. Additional detail on objectives, approach, and milestones for each program is provided in the Appendix.

Environmental Protection Agency (EPA)

EPA sponsors studies to support its activities related to aircraft regulations. The FY 1973 and FY 1974 projects, which are most relevant, for inclusion here, are listed in Table 8.2.

Table 8.1 NASA NOISE RELEVANT AIR TRANSPORTATION SYSTEMS STUDIES NOISE RELEVANT PROGRAM COSTS
(Thousands of Dollars)

Descriptive Title	FY 1974			FY 1975			FY 1976		
	Gross R&D	Manpower Costs	Total	Gross R&D	Manpower Costs	Total	Gross R&D	Manpower Costs	Total
Short-Haul Transportation Systems Analysis	150	30	180	-	-	-	-	-	-
Analysis of Future Civil Transportation Systems and Concepts	61	27	88	120	48	168	120	27	147
High Transonic Speed Transport System Study	15	1	16	80	-	80	80	-	80
Subsonic/Transonic C/RTOL Transport Tech. Systems and Design Studies	80	30	110	-	-	-	-	-	-
Subsonic/Sonic Transportation Technology Propulsion Studies	28	6	34	-	-	-	-	-	-
TOTALS	334	94	428	200	48	248	200	27	227

Table 8.2 EPA AIRCRAFT NOISE SYSTEMS STUDIES

Project Title	Contracting Organization	Contract Number	Project Manager	Key Dates		Amount, thousands of dollars
				Start	End	
Aircraft/Airport Operations Noise Study	Bolt, Beranek & Newman	68-01-1835	J. Schettino	4/73		182
Installation, Refinement and Training in Utilization of USAF-NEF	Bolt, Beranek & Newman	68-01-2265	D. Gray	2/74	2/75	79
Aircraft/Airport Study: Legal Analysis	George Washington University	68-01-1834	E. Cuadra	4/73	9/73	110
Development of Implementation Tools for Administration of Airport Noise Regulation	E. H. Robbins	68-01-2266	E. Cuadra	2/74	4/75	33
TOTAL for FY 73 & 74						404

9. GENERAL AVIATION NOISE RELATED TECHNOLOGY

Many of the noise related programs presented in other sections of this report have application to general aviation aircraft. In particular, the NASA programs, Basic Noise Research and Noise Technology, involve studies of propeller noise reduction. DOT/FAA also conducts studies relevant to general aviation aircraft; however, these are included in Section 8 since it is difficult to isolate this activity from cost and program scheduling data.

National Aeronautics and Space Administration

The title and statement of objective of the NASA programs dedicated specifically to general aviation aircraft are:

- General aviation aerodynamic technology. To develop and demonstrate advanced technology for general aviation use that will permit the design of future U.S. aircraft that will be safer, more productive, and clearly superior to foreign competition.

- Quiet, clean general aviation turbofan (QCGAT). To identify, extend, and demonstrate the technology applicable to small general aviation turbofans to achieve future environmental requirements with economic viability.

Table 9.1 shows the major study categories and the funding in the general aviation aerodynamic technology program. The Appendix contains an expanded discussion of this program.

Table 9.1 NASA NOISE RELEVANT GENERAL AVIATION AIRCRAFT TECHNOLOGY STUDIES
NOISE RELEVANT PROGRAM COSTS
(Thousands of Dollars)

	FY 1974			FY 1975			FY 1976		
Descriptive Title	Gross R&D	Manpower Costs	Total	Gross R&D	Manpower Costs	Total	Gross R&D	Manpower Costs	Total
Aerodynamics and Crashworthiness	65	30	95	-	-	-	-	-	-
General Aviation Technology	200	60	260	250	198	448	370	90	460
Quiet, Clean General Aviation Turbofan (QCGAT)	-	-	-	-	-	-	400	136	536
TOTALS	265	90	355	250	198	448	770	226	996

10. REFERENCES

1. Civil Aviation Research and Development Policy Study. Report DOT TST-10-4, NASA SP-265; Supporting Papers DOT TST-10-5, NASA SP-265. March 1971.

2. Aircraft Noise Reduction Technology. A report by the National Aeronautics and Space Administration to the Environmental Protection Agency for the Aircraft/Airport Noise Study, March 30, 1973. This report gives a technical treatment of progress, status, and planned research by NASA relative to aircraft noise. (Unpublished)

3. Federal Noise Effects Research: FY73-FY75. A report prepared by the Interagency Noise Effects Research Panel, for the U.S. Environmental Protection Agency: EPA Report #600/2-75-001. March 1975. (31 pages.)

11. GLOSSARY OF ACRONYMS AND TERMS

AMST - Advanced Medium STOL Transport.

ARC - Ames Research Center.

C/RTOL - Conventional/Reduced Take Off and Landing.

CTOL - Conventional Take Off and Landing.

DOD - Department of Defense.

DOT - Department of Transportation.

EPNdB - Effective Perceived Noise Level in dB.

FAA - Federal Aviation Administration.

FAR-36 - Federal Aviation Rule, Part 36.

FRC - Flight Research Center.

FY - Fiscal Year.

HiTST - High Transonic Speed Transport.

JP-Fuel - Jet Petroleum Fuel

JPL - Jet Propulsion Laboratory.

L/D - Lift-Drag Ratio.

LaRC - Langley Research Center.

LeRC - Lewis Research Center.

NASA - National Aeronautics and Space Administration.

ONA - Office of Noise Abatement.

QCSEE - Quiet Clean Short-Haul Experimental Engine.

QSRA - Quiet Short-Haul Research Aircraft.

RD&D - Research, Development, and Demonstration.

RSRA - Rotor Systems Research Aircraft.

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RTOL - Reduced Take Off and Landing.

RTOP - Research and Technology Operating Plan.

SAM - Sound Absorbing Material.

SCAR - Supersonic Cruise Aircraft.

STOL - Short Take Off and Landing.

USAF - United States Air Force.

V/STOL - Vertical/Short Take Off and Landing.

VTOL - Vertical Take Off and Landing.

12. APPENDIX - COMPENDIUM OF AIRCRAFT NOISE RELATED FEDERAL PROGRAM PLANNING AND PROJECT DESCRIPTIONS

This document contains detailed program planning information of the Federal Agencies' Aircraft noise research, development, and demonstration activities. The information and data are presented basically in the form submitted to EPA through the agencies' representatives on the Aircraft Noise Research Panel. This document can be viewed as the status of programs and plans as of July, 1974.

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NOISE REDUCTION FLIGHT PROCEDURES EXPERIMENTS

(768-80) Ongoing

Program Objective

Reduce 90 EPNdB approach noise footprint by at least 60% through scheduled airlines' demonstrations of avionic systems for noise abatement flight procedures.

DOT considers the two-segment approach procedure to be the most promising operational noise abatement technique now under evaluation and an important part of the overall noise reduction program.

Program Targets

NASA will demonstrate operational avionics and flight procedures that can be used to reduce airport community noise through the following steps:

- Complete six month trunk airline demonstration of two-segment approach with a B-727 in scheduled air-line service - November 1973.
- Complete six-month trunk airline demonstration of two-segment approach with a DC-8 in scheduled air-line service - October 1974.
- Demonstrate potential of other operating techniques for reducing aerodynamic and propulsion noise on approach and landing - January 1976.

Program Approach

The NASA program for noise reduction has placed primary emphasis on the two-segment approach, which offers significant benefits.

- For reduced noise impact
- At a relatively small cost
- With the potential of early implementation

Program activities are closely coordinated with the FAA and the Joint ODT/NASA Office of Noise Abatement. They are being managed by the Ames Research Center with participation by the airline industry, airline

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pilots, avionic manufacturers, and air traffic controllers at several airports.

Two avionic system concepts are being evaluated. The main differences between the concepts are the techniques that will be used to establish the upper segment glide slope guidance. One concept, for aircraft not equipped with area navigation, will cost approximately $37,000 installed. The other concept, based on modification of area navigation equipment already installed in the aircraft, will cost approximately $9,000.

The program involves analysis, simulation, flight test, and in-service evaluation in two aircraft types: the B-727, and DC-8. The applicability of the procedures over the remainder of the fleet of current jet transports will be evaluated by analysis and simulations.

Over 1200 two-segment approaches have been made in the B-727 by over 120 pilots from 13 airlines at five airports. Of these, approximately 600 approaches by 58 line pilots have been made in passenger carrying service.

Preliminary results:

- Have obtained line pilot acceptance in one airline in one type aircraft:
    - Procedure has been demonstrated to be safe
    - Procedure can be interfaced with today's ATC environment
    - Avionics system provides good navigation accuracy on upper segment
    - No significant increase in pilot workload
    - Passenger comfort not affected
- Two-segment approach provides approximately 60% reduction in the 90 EPNdB approach noise footprint area for the B-727.

Research continuing into FY 75 includes the DC-8 in-service evaluation, investigations of the effects of operating procedures on aerodynamic and propulsive noise, and development of procedures that achieve maximum noise reduction.

Investigations have been conducted on a preliminary evaluation of the wake vortex behind and below jet aircraft flying a two-segment approach in order to determine if any additional hazard exists to following aircraft.

Need and Relevancy

The NASA in cooperation with the FAA and the airlines has been involved in developing and evaluating the operational procedures for noise reduction for a number of years. The landing approach studies indicated potentially large noise reductions could be achieved by three noise reduction approach techniques: the two-segment approach, the energy management of decelerating approach, and the curved ground tracts approach. Although it was found that these flight procedures are well within the performance capability of current day jet transports, they impose new requirements on the pilot duties and workload, on the pilot displays, on the guidance and navigation system, on the aircraft control system, on the ATC flow of aircraft to high density runways, and possible different wake turbulence effects. NASA decided in 1971 to embark on a substantial effort to develop suitable avionics for noise abatement procedures and to obtain sufficient experience so that they are accepted for routine operations.

In July 1973, the Administrator of the Environmental Protection Agency submitted a "Report to Congress on Aircraft/Airport Noise" in compliance with the Noise Control Act of 1972. The purpose of the report is to recommend ways in which the public health and welfare can be protected from excessive aircraft noise.

The following excerpts from this report reinforce the soundness of NASA's decision relative to the need and relevancy of procedural methods of aircraft noise reduction.

"Approximately 16 million persons are presently impacted by aviation noise in the United States, and in spite of the introduction of quieter new aircraft, the number will continue to be of major proportion until the mid-1980's unless aggressive action is taken."

"Aircraft noise around airports is presently a principal constraint on the future growth of the air transportation system."

"It is evident that there is a need to mobilize available resources and technology, including those of providing newer and quieter aircraft for the future, to deal with this problem in a coordinated time-phased fashion."

"If noise levels protective of the public health and welfare are to be achieved around the Nation's airports in the near future, it will be necessary to establish a Federal regulatory program which effectively combines Federal controls on aircraft flight procedures, technology, and noise control options available to airport operations and local jurisdictions."

"From the foregoing, it can be seen that a number of noise abatement flight procedures are available for implementation. Although by themselves, they cannot totally resolve the noise problem, they play an important part in any comprehensive plan for noise abatement."

"The two-segment approach seems to hold the most promise (of several different noise abatement approach procedures) for significant approach relief."

"The main objections to two-segment approaches come from ALPA pilots and some segments of the airline industry. They desire more testing to be certain that safety will not be degraded by the higher descent rates in the steep segment."

"EPA also concludes that two-segment approaches in IFR conditions are technically feasible after installation of equipment currently available in prototype form. Such approaches are expected to be consistent with the highest degree of safety upon completion and evaluation of the current NASA test program and certification of the equipment."

The Noise Reduction Flight Procedures Experiments program is being conducted by the NASA Office of Aeronautics and Space Technology to be responsive to the national need to protect the public health and welfare from aircraft noise.

TERMINAL CONFIGURED VEHICLE OPERATING SYSTEMS EXPERIMENTS

(768-81) Ongoing

Program Objective

Identify and provide proven technology and operating techniques for advanced CTOL and RTOL aircraft for reducing approach and landing accidents, reducing weather minima, increasing air traffic controller productivity and airport and airway capacity, saving fuel by more efficient terminal area operations and reducing noise by operational procedures during the 1976-2000 time period.

An expression by the U.S. scheduled airlines through the Air Transport Association on the desired direct thrust and content of the government's aviation research and development efforts proposes a research, development and applications engineering effort with three major work areas: (1) solution of environmental problems; (2) air traffic control process development and automation; and (3) aircraft and aviation support systems improvement.

Program Targets

Major targets of this program include technology readiness in the late 1970's for:

- Precision 4D flight path control by FY 1976 for

  -improved accuracy of time of arrival at runway from 18 sec. to 5 sec.

  -decreased spacing between parallel runways from 5000' to 3000'.

- Steeper, curved, and decelerating landing approach - FY 1976.
- Automatic landings in zero visibility - FY 1977.
- Reduction of the impact of aircraft on the environment in terms of aircraft noise and air pollutions FY 1976.
- Landing rates in IFR which approach VRF rates - FY 1977.
- Guidance and control capability for reduction in separation between aircraft or landing approach from 3 and 5 miles to 1 and 2 miles - FY 1976.
- Reduction in runway occupancy time from 55 sec. to 25 sec. - FY 1977.
- Avionics which interface with an advanced ATC system - FY 1978.
- Greater safety - FY 1979.
- Improved productivity by minimizing terminal area delays - FY 1979.

Program Approach

NASA and FAA are working together on this program, under a joint agreement. The program is being managed by the Langley Research Center with most of the flight experiments being conducted from Wallops Station.

In comparison with existing transport aircraft, a terminal configured CTOL or RTOL aircraft should possess improvements in the following areas: greater flight path flexibility; less pollution and noise; improved acceleration, deceleration and lift capability; slower approach and departure speeds; closer spacing without wake vortex hazard; more accurate position, speed, and time control; less time on the runway, less sensitivity to wind and weather; greater speed flexibility; safer and better handling qualities; and reduced operating costs. To define operational systems needed to produce the above improvements and to identify areas where technology emphasis should be placed, initial attention in this program will be placed on analytical and experimental studies. Later, simulation and flight evaluation will be the primary tools in carrying out this program.

Plans for the program include research in conjunction with the Microwave Landing System (MLS), now under development by the FAA, and applying the greater accuracy and reliability of digital computer techniques to what are presently analog avionic systems. The MLS opens up many opportunities for improvement in terminal area operations because the aircraft is freed from the standard one-course ILS approach. Present aircraft instrument approach systems are not compatible with MLS.

Flight experiments using advanced displays and performing precision 4D flight paths in a uniquely equipped B-737 aircraft will commence late in FY 74. This research will continue heavily in FY 75 with particular emphasis on improving adverse weather approach and landing capability and safety through use of advanced displays and flexible, automatic digital flight control and guidance systems. Available and simulated advanced radio navigation aids will be utilized in flight tests at Wallops Station. Flight simulation and analysis work will lead and support flight tests. Feasibility demonstrations of advanced equipment will be conducted at key points during the program.

Additional details are available in the Dec. 1, 1973 Program Plan entitled, "Terminal Configured Vehicle Program."

Need and Relevancy

The following excerpts from The National Aviation System Policy Summary, March 1973, which summarizes the FAA policies for the development of National Aviation System over the next ten years, clearly state the need and relevancy of the objectives of this program:

> "Thus, in consonance with National Transportation System goals, the broad technical goals over the next ten years can be summarized as follows:
>
> - Increase airport capacity
> - Increase airway capacity
> - Improve airway and airport safety
> - Minimize system operating costs
> - Minimize the impact of air transport on the environment"
>
> "The heart of the present air traffic problem lies at five high-density terminal locations where congestion and costly delays occur during adverse weather conditions and regularly during the peak hours. Without system improvements, the number of terminals experiencing such congestion is expected to increase to 21 by 1981."
>
> "Of all the major issues, this (the impact of environmental concerns on aviation systems development) is potentially the most important."
>
> "Long range impacts of the energy problem on aviation are still unclear, but it is quite probable it will act as a constraint on expanded aviation service."

These positions are supported by many others; for example, the DOT Air Traffic Control Advisory Committee and the Joint DOT/NASA Civil Aviation Research and Development Policy Study.

Since the problems of safety, adverse weather, noise, congestion, and fuel wastage manifest themselves most strongly in the high density terminal area, this program is concentrating on the terminal area performance characteristics of civil transport aircraft. Terminal area air traffic control is not merely a combination of procedures and hardware, but is a complex system involving people, aircraft, airports, and airport neighbors. All elements of the system must be studied in relation to each other and to their environment. The terminal area performance characteristics of aircraft are vital parameters in air traffic control.

If the long-term rate of growth of air transportation continues, airplane characteristic improvements in combination with planned FAA improvement in the ground system have the potential benefits of:

- Improvement of runway operations by 50 to 150%.
- Saving an average of 750,000 gallons of fuel per transport aircraft per year.
- Reducing the cost of delays by ½.
- Saving passenger time valued at more than $100M per year.
- Maximizing the effectiveness of the FAA Third and Fourth Generation ATC Systems.

In order to provide the system operating technology in a timely and effective manner, the TCV program will undertake to identify gaps in the current technology of operating systems (such as displays and aircraft performance requirements), and generate solutions which will permit more efficient terminal area operations. It is important that the TCV program be conducted in a time frame that is compatible with planned improvements in the National Aviation System. In order that the advanced airborne technology and systems required to interface with the future ATC system being developed under FAA leadership are available by the mid 1980's, they must be essentially demonstrated by the late 1970's. The planned schedule of TCV activities is designed to accomplish this purpose.

Safety of aircraft occupants is of fundamental importance in an air transportation system. Through a 60-plus year history of operations, accidents have provided clear and sometimes not so clear indications of hazard areas. With the advent of more reliable jet engines, en route accidents due to piston engine failure, severe weather encounters, and in-flight fires as well as takeoff accidents due to engine failure have declined as major accident prone areas, leaving the approach and landing phase accounting for more than half the fatal accidents. Offsetting higher approach and landing impact speeds as a threat is the improved structural integrity of modern aircraft and improved passenger seat retention. Control systems are more sophisticated, and navigation/communication is exceedingly complex by 1950 standards, and decision times for critical events in the landing process are short, all of which add up to more stress on the pilot's judgement and decision process. This makes an error in judgement potentially more dangerous in terms of an accident. A systems analysis will provide a rational assessment of potential accident-prone areas in flight operations.

TCV experiments will lead to reduced pilot workload by improved flight deck design, better understanding of crew inter-personal relationships, and automation. The aft flight deck of the 737 RSFS will provide a unique facility for man-vehicle (human factors) technology development.

The potential for significant reduction of approach and landing accidents is considered high.

Not only is the activity conducted under this program relevant to our efforts to ensure future airplanes capability to meet forecast traffic demand without adverse effect on safety and airport communities, it is aimed at putting the U.S. industry on a more competitive basis in world markets of manufactured aircraft and aeronautical equipment.

REFAN PROGRAM
(739-14)

Program Objectives

Provide the technology to obtain a 75 percent reduction in the noise footprint area of JT8D-powered aircraft (727, 737 and DC-9) which account for over 60 percent of domestic fleet operations.

Furnish FAA and EPA with the technological and cost data essential for consideration of rulemaking on engine retrofits.

Program Targets

Major targets of the Refan Program are the following:

- Complete the design of the refanned JT8D engine and acoustic nacelles for 727 and DC-9 aircraft by July 1973.
- Verify the predicted aerodynamic and acoustic performance of the refanned engine with ground engine tests starting in February 1974.
- Demonstrate the objective of 75 percent noise reduction with refanned engines and 727 aircraft nacelles by ground tests starting in February 1975.
- Demonstrate the objective of 75 percent noise reduction by actual flight tests of a DC-9 aircraft starting in February 1975.
- Final economic and performance data to FAA by June 1975.

Program Approach

The approach to accomplishing this objective is to develop modifications for the JT8D engine that can be produced as retrofit kits, develop nacelles with acoustic treatment for the modified engines, and demonstrate the noise levels and performance levels of a DC-9 airplane in flight and a 727 propulsion system in ground tests.

The JT8D engine will be modified by replacing the existing two-stage fan with a larger diameter single-stage fan employing wide spacing between the vanes and rotor. The core engine pressure and flow will be maintained by two booster stages in front of the compressor. The fan turbine last stage rotor blade will be recambered. These changes will increase the engine thrust and lower the core jet velocity for the same cycle temperature. The lower jet velocity will result in decreased jet mixing noise. Acoustic treatment will be added to fan ducts and other acoustic devices will be considered to select an optimum engine nacelle. In the interest of minimizing the cost of the retrofit kit, no modifications will be made to any engine or airframe components unless they are necessary for or contribute directly to the substantial reduction of noise.

The program will be conducted through contracts with engine manufacturers, aircraft manufacturers and airline operators. NASA inhouse effort will be used both to manage the contracted efforts and to directly support the program through studies and tests in NASA facilities. The first phase of the program, completed in June 1973, established the refanned engine and nacelle definition through analysis, design and limited component testing. The second phase of the program, starting in July 1973, will culminate in ground tests of a 727 refanned propulsion system and flight tests of a refanned DC-9 aircraft both in February 1975.

Need and Relevancy

The environmental impact of aircraft noise has been identified as a critical factor limiting the growth of civil aviation. Vigorous public reaction to the annoyance of aircraft operations has stifled civil air system expansion, produced costly litigations, and resulted in operational constraints which limit airport capacity and constrain aircraft procurement. Demonstration of the refan feasibility provides a basis for implementation of a refan retrofit which would reduce the noise footprint areas of the aircraft principally responsible for the high community noise exposure by 75 percent. Further, these same modifications can be introduced in the production of new 727, 737, and DC-9 aircraft to result in quieter, new aircraft.

OBJECTIVE NO. 766-78
ADVANCED ACOUSTIC COMPOSITE NACELLE FLIGHT PROGRAM

Program Objective

Demonstrate on a modern wide-body transport in airline operation the application of advanced interwoven acoustic absorbent and composite structural materials to an engine nacelle which will:

- Reduce the noise footprint area of future production wide-body transport aircraft by 30 percent with no increase in aircraft weight or fuel consumption or alternatively reduce aircraft weight and fuel consumption with no increase in noise.

- Together with advanced technology engines, reduce the 90 EPNdB noise footprint area of advanced technology transport aircraft to 2 square miles with no increase in aircraft weight or fuel consumption resulting from the nacelle or alternatively reduce aircraft weight and fuel consumption together with some noise reduction.

Program Targets

Recent materials and structures developments at Langley Research Center on interwoven acoustic and composite materials offer the promise of considerable reduction in operating costs. This program will exploit these materials to:

- Complete nacelle concept definition studies and verify approach by January 1976.

- Complete ground tests of an advanced technology nacelle by early 1979.

- Certify an advanced nacelle for airline service on a wide-body transport by late 1979.

- Demonstrate quiet nacelle performance in routine airline service by 1982.

Program Approach

Current technology using uniform wall treatment basically attenuates the noise by the addition of acoustic absorbent materials to the structural materials. A promising advanced technology noise suppression technique embodies a reflection principle in addition to attenuation to decrease noise transmission. This is accomplished by interweaving acoustic absorbent and structural materials in a composite material form and thereby forming an acoustic structural material. By using multiple changes in wall acoustic treatment (segmented treatment), lower net transmission is achieved. The performance of the technique is striking - experimental results indicate about 15dB-reduction in sound intensity compared to the same weight of metalic material with added acoustic absorbent material. Utilization of the acoustic composite material can further eliminate the inlet and duct splitter rings which are currently used for noise suppression together with their associated drag and fuel penalties.

The project will be based on FY 1974 studies to determine areas where the application of composites with integrated acoustic material has the greatest payoff with respect to weight, cost, and noise reduction. The experimental program will be carried out in two phases. The first phase consists of preliminary design of the engine nacelle to be tested. The second phase will include the detail design, fabrication, and testing of the nacelle. The program, will: (1) evaluate various design concepts for the integration of composite materials with nacelle acoustic treatment in terms of initial cost, noise reduction, weight reduction, maintenance cost, and feasibility of application to existing propulsion systems as well as to advanced installations; (2) develop the technology associated with selected design concepts by means of analyses, ground tests, and limited flight tests and perform all analyses and tests required for commercial application; and (3) perform ground tests, and flight tests in commercial service, of production composite/acoustic nacelles to provide sufficient data on performance, maintenance requirements, and maintenance costs to establish aircraft and airline industry confidence in the application of composites to engine nacelles.

Overall direction and coordination of the Program will be accomplished by the OAST Transport Experimental Programs Office. The Langley Research Center will be designated the lead Center for the project with support by Lewis Research Center (propulsion activities). Program coordination with DOT/FAA and with the airlines will be maintained and nacelle certification will be under the direction of the FAA.

Need and Relevancy

The ICAO World Traffic Forecast for air passenger demand indicates a potential fivefold increase in air passengers by the mid 1980 period. The number of air passenger seats required is approximately double the number now available and on order. While the world fuel crisis may in time result in modification of this projected growth in demand for air transportation, the demand will certainly increase.

Market studies indicate that the bulk of this aircraft seat need will be met by new wide-body type aircraft. Current and quieted narrow-body aircraft will begin to be removed from service and the world aircraft fleet will be made up largely of wide-body aircraft certified to meet current noise regulations. Other types of aircraft such as advanced technology transports, SSTs, and STOLs will contribute to air lift capacity but to much less extent than current type wide-body aircraft.

With such a fleet mix, community noise exposure is expected to again increase during the 1980 period unless steps are taken now to provide technology which will permit noise reduction without fuel consumption penalties. The acoustic composite nacelle flight program is designed to serve that need.

a. NASA July 25, 1974 Testimony on Aircraft Noise Programs before the House Subcommittee on Aeronautics and Space Technology

RESEARCH AND TECHNOLOGY FOR AIRCRAFT NOISE ABATEMENT

Statement of

J. Lloyd Jones
Deputy Associate Administrator for Aeronautics Technology
Office of Aeronautics and Space Technology

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Before the

Subcommittee on Aeronautics and Space Technology
Committee on Science and Astronautics
House of Representatives

Mr. Chairman and members of the Subcommittee, I am pleased to have this opportunity to bring the Subcommittee up to date on NASA's activity related to the abatement of noise in the present and projected civil air transportation fleet. As you know, we consider this an important public matter and have given it considerable attention over an extended period of time.

Today I will present a brief report on the progress of our work on the refan retrofit option for civil aircraft certificated before Federal Air Regulation Part 36 came into effect; and on the result of a meeting on the Refan Program and related regulatory activity between Dr. Fletcher, Administrator of NASA, Mr. Barnum, Under Secretary of DOT, and Mr. Meister, Associate Administrator for Plans of FAA, attending for Mr. Butterfield, Administrator of FAA, and attended by Mr. Strelow, Acting Assistant Administrator for Air and Waste Management of EPA, attending for Mr. Train, Administrator of EPA. I will also report on the progress made on NASA's Two-Segment Approach Program, the coordination of aircraft noise abatement programs, and NASA programs to provide data for the reduction of noise in the near and long term.

Before discussing our programs, I would like to note that NASA is concerned primarily with the technological aspects of aircraft noise abatement. The treatment of all the complex factors (economic, social, operational, and foreign) associated with regulation are the responsibility of other branches of government, noteably DOT, FAA, EPA, and OMB.

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REFAN PROGRAM SCHEDULE

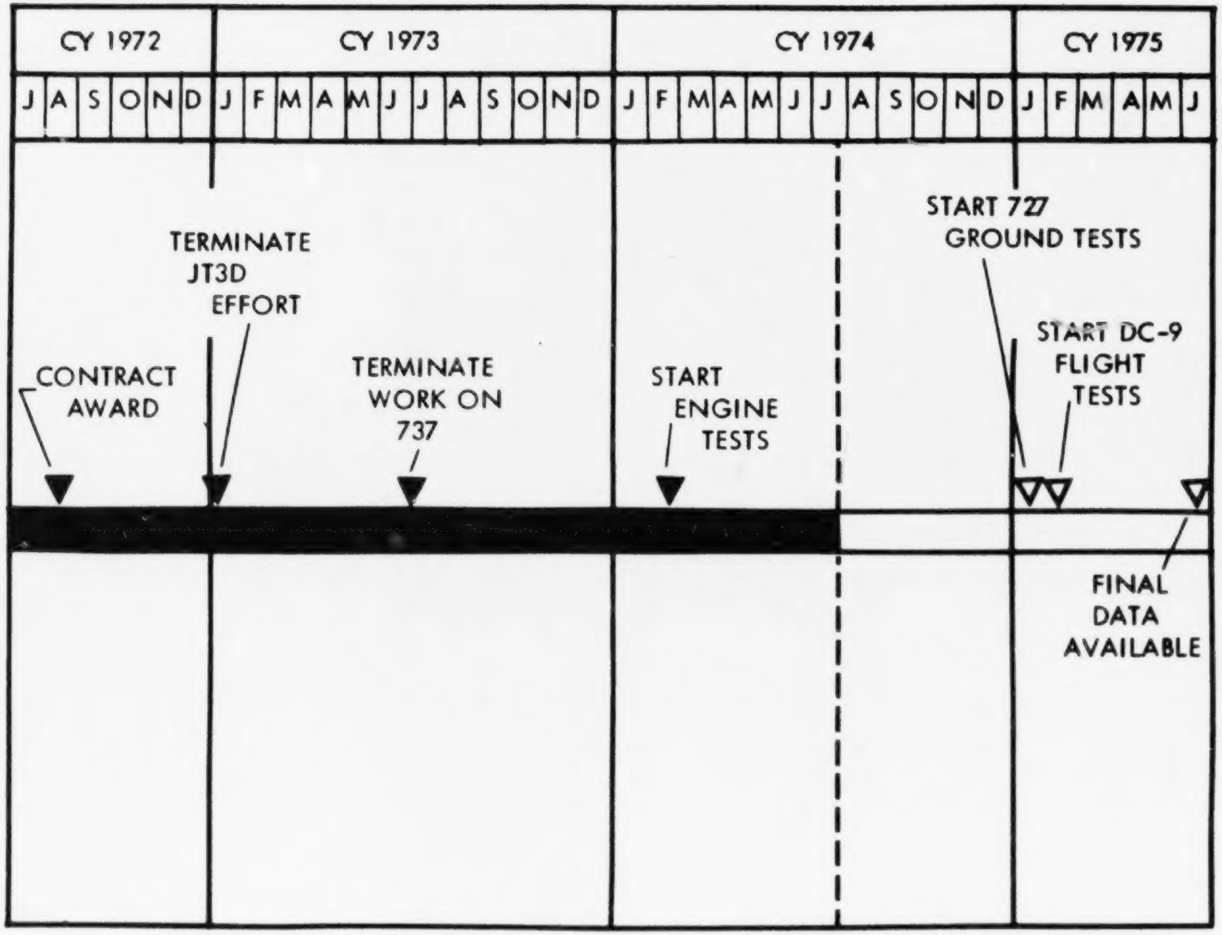

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FIGURE 1

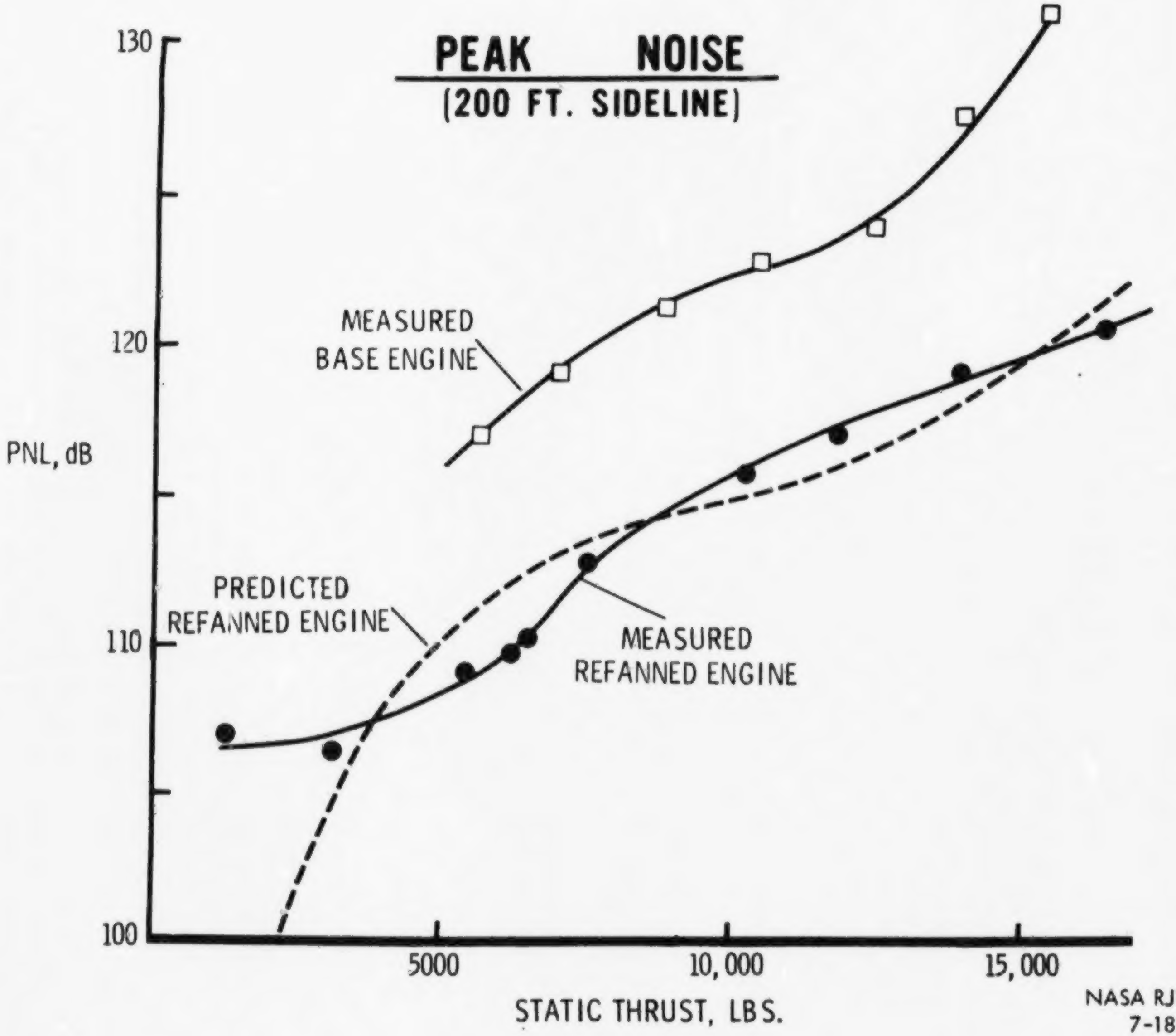

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FIGURE 2

Thus, the comments and data we present are not the sole basis for decisions in the complex arena of noise abatement.

REFAN RETROFIT

As you know, NASA's part of the retrofit program is to develop and assess the costs, effectiveness and technical feasibility associated with refanning the JT8D-powered fleet. This program has been described in detail to the Subcommittee in previous hearings. Figure 1 presents the program schedule discussed with the Subcommittee at its hearings in December of last year. All of the major milestones are being met. The testing of refanned JT8D engines began in February as planned. Our schedule still calls for initiation of detailed ground tests with the 727 airplane refan hardware in January of 1975, about six months from now. The DC-9 airplane refan flight tests will start a month later, in February. An updated assessment of the Phase I acoustic and performance design estimates for the 737 will be developed after the 727 and DC-9 tests. Final data will be available by June of 1975.

A substantial amount of data on the mechanical, aerodynamic and acoustic performance of the refanned engines is now in hand. Two engines have been tested extensively and testing of a third engine begins this month.

Figure 2 shows a typical result from the refanned engine acoustic tests, the peak noise level of the engine measured at the 200 foot sideline. The top curve on the figure shows the data from a standard JT8D-9 engine plotted against engine thrust. The lower solid and dashed curves are the measured and predicted noise levels for the refanned version of the engine. The measured and predicted noise levels are in good agreement.

On the basis of the engine acoustic results, new baseline aircraft data, and new analysis procedure, the airframe contractors have revised their estimates of the noise levels of the DC-9 and 727 aircraft. These estimates are still under study by the Refan Project Office at the Lewis Research Center. Although the measured overall noise of the refanned engine was as predicted, the distribution of the noise among the various engine components was not. The distribution of component noise affects the calculated aircraft noise. Further acoustic tests at Pratt and Whitney and further analysis of the acoustic data are needed to establish confidence in the aircraft noise predictions.

Specific fuel consumption (SFC) is also an important factor in assessing retrofit options. In the March 1974 Authorization Hearings we noted that preliminary measurements of SFC for retrofitted engines were higher than estimates and corrective action was being considered. Minor engine changes have been made and further tests have been conducted.

The basic predicted improvement in SFC for the uninstalled refanned engine has been achieved over most of the engine thrust range. At maximum power the increment of improvement was less than predicted by about two percent. Furthermore, the absolute level of SFC is higher than predicted. This is thought to have resulted from the fact that the SFC of the basic engine that was modified to provide the refan test engine was higher than that of a new engine. Refanning, therefore, resulted in largely achieving the predicted incremental reduction in SFC but not the absolute level expected. We do not know whether the same improvement in SFC will be realized for a new engine conversion to a refanned engine. A new engine, refanned, is being tested this month and we will soon have the answer to this question.

It should be noted that the tests to date were conducted at sea level static conditions. The translation of these test data to altitude cruise conditions is uncertain. The SFC could be high by as much as the 2 percent experienced at the maximum power conditions. Better SFC data for altitude cruise will be available some time after August as a result of wind tunnel flight simulation tests to be conducted at the Lewis Research Center.

Assuming we achieve our predicted values of SFC at all conditions the estimated changes in block fuel due to refanning the 727 and DC-9 aircraft shown in Figure 3 should be realized. For some combinations of altitude, speed, and distance, fuel is increased as much as 3 percent and for others it is decreased as much as 1 percent. As you see, the impact of refanning on fuel usage is estimated to be small and a function of specific operating conditions. A refined analysis of specific airline operations would be required to substantiate gain or loss for a specific operator.

As we have discussed with you before, the refan technology is a higher cost technology than sound absorption material alone. The investment cost for a retrofit of the JT3D- and JT8D-powered fleets with SAM is estimated to be $667 million, in the 23 airport study of the Joint DOT/NASA Office of Noise Abatement, whereas a retrofit of the JT3D-powered aircraft with SAM and the JT8D-powered aircraft with refan is estimated to be $2.82 billion, or more than four times as much as a complete SAM retrofit. These numbers are based on assumptions of inflation rate and starting schedule for the SAM and refan retrofits that are necessarily subject to uncertainty. In 1973 dollars, the cost of a SAM JT3D and refan JT8D retrofit is $1.95 billion.

In addition to the initial investment cost there are other costs associated with a fleet retrofit that would increase the cost of the SAM JT3D/Refan JT8D retrofit program. The current estimate in the 23 airport analysis would indicate a total cost of about $5 billion. These additional costs include consideration of changes in direct

BLOCK FUEL CHANGES FOR REFANNED AIRCRAFT

(55 - 60 PERCENT LOAD FACTOR)

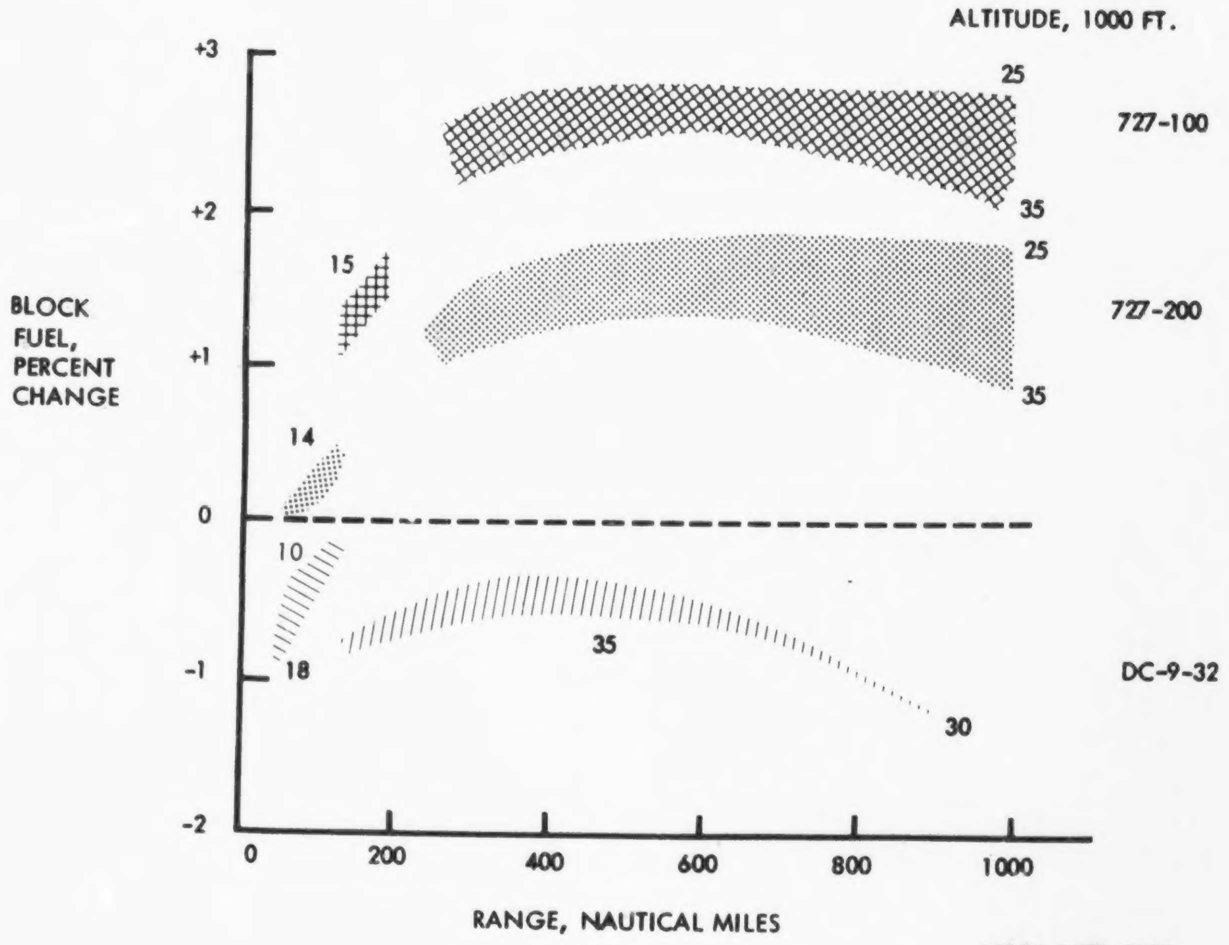

FIGURE 3

NASA RJ75-2330
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operating cost (DOC) over the projected life of the aircraft, "lost productivity" resulting from the retrofitted aircraft being unable to perform maximum range missions because of increased weight, and the aircraft being out of service during the retrofit installation.

There are sufficient uncertainties in evaluating these additional factors, excluding the assumed inflation rate and retrofit schedule, that the $5 billion cost could be over-estimated. These complex factors are currently being discussed with DOT to develop a realistic accounting procedure.

We have provided data to DOT, FAA, and EPA on all aspects of the Refan Program: acoustics, performance, and cost. As the program moves into the final stages we will continue to provide data needed to these agencies for their deliberations regarding retrofit.

REFAN PROGRAM/REGULATORY ACTIVITY REVIEW

At our March 6, 1974 hearings before this Subcommittee, we advised you that the Under Secretary of DOT, and the Administrators of FAA and NASA were planning a series of meetings to review the progress of the Refan Program and the plans for related regulatory activity. A meeting of this group was held this past July 22. At this meeting, the Refan Program progress was reviewed as well as the results of the Joint DOT/NASA Office of Noise Abatement study of the effects of various retrofit and operational techniques for noise reduction at 23 airports. In addition, the position of DOT/FAA on regulatory action for retrofit was reviewed.

At this July 22 meeting, it was concluded by DOT/FAA that there was nothing new to warrant a change in the DOT/FAA position on the retrofit NPRM. It was concluded by NASA that the Refan Program should continue exactly as planned because of the technological advances provided by the program, the possible use of refanned engines in derivative aircraft, and the need for keeping the technological option for lower noise levels in the future.

THE TWO-SEGMENT APPROACH PROGRAM

I will now move on to discuss our two-segment approach activity. We have described this program, supported by the FAA, in past testimony. As you know, the objective of the program is to provide a significant near-term reduction in the aircraft landing approach noise through the provision of operational avionics and flight procedures that can be used safely by airlines in both visual and instrument flight.

I will review for you briefly the program approach, the results of the 727 in-service flight program, and update you on the in-flight evaluation with the DC-8 aircraft.

The Two-Segment Approach Program, managed by our Ames Research Center, is closely coordinated with DOT, FAA, and EPA. Program guidance has been provided by a Research and Technology Advisory Ad Hoc Panel on Noise Abatement Flight Procedures. Its members came from DOT, FAA, aircraft and avionics manufacturers, airlines, and the airline pilots' association.

Figure 4 shows one version of the two-segment guidance equipment required in the airplane to permit either manual (flight director) or automatic (autopilot) two-segment approaches. This airborne equipment requires ground based distance measuring equipment (DME), co-located at the instrument landing system (ILS) glide slope transmitter.

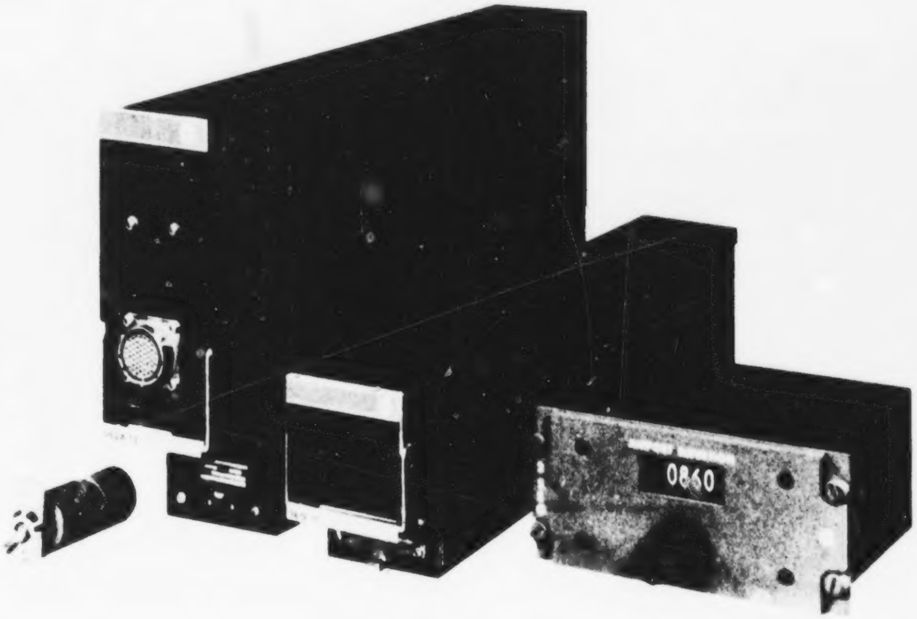
Briefly, the two-segment approach technique can be described as follows. A special airborne computer constructs a preselected upper glide slope (normally 6°) using barometric altitude and distance information from the DME. Field elevation is set-in by the pilot before the approach is initiated. On an approach, the upper glide slope is captured by the aircraft and the descent initiated. At about 1000 feet above ground level the computer programs a gradual round out. Then, the lower nominal 3° glide slope is captured and tracked as on a conventional approach. At an altitude of about 500 feet, the airplane is stabilized on the 3° glide slope and goes on to a normal landing.

The cost of the two-segment guidance system, illustrated in Figure 4, is approximately $40,000 per aircraft for a dual installation. To add two-segment guidance to an existing three-dimensional area navigation system, such as shown in Figure 5, would cost approximately $9,000 for a dual installation. For this system the DME need not be co-located with the ILS glide slope transmitter. The costs noted include the basic equipment, aircraft modification and installation, check-out spares and training, and as noted dual installations. Dual installations, however, may not be required.

The 727 Two-Segment Approach Program

The 727 Two-Segment Approach Program has been completed. It had two objectives: to develop operational avionics and two-segment flight procedures for safe use with 727's in routine scheduled operations; and, to conduct a six month evaluation in revenue service. The special avionic equipment illustrated in Figure 4 was used.

TWO-SEGMENT APPROACH SYSTEM COMPONENTS FOR NOISE ABATEMENT FLIGHT PROCEDURES PROGRAM



TWO-SEGMENT APPROACH
COMPUTER

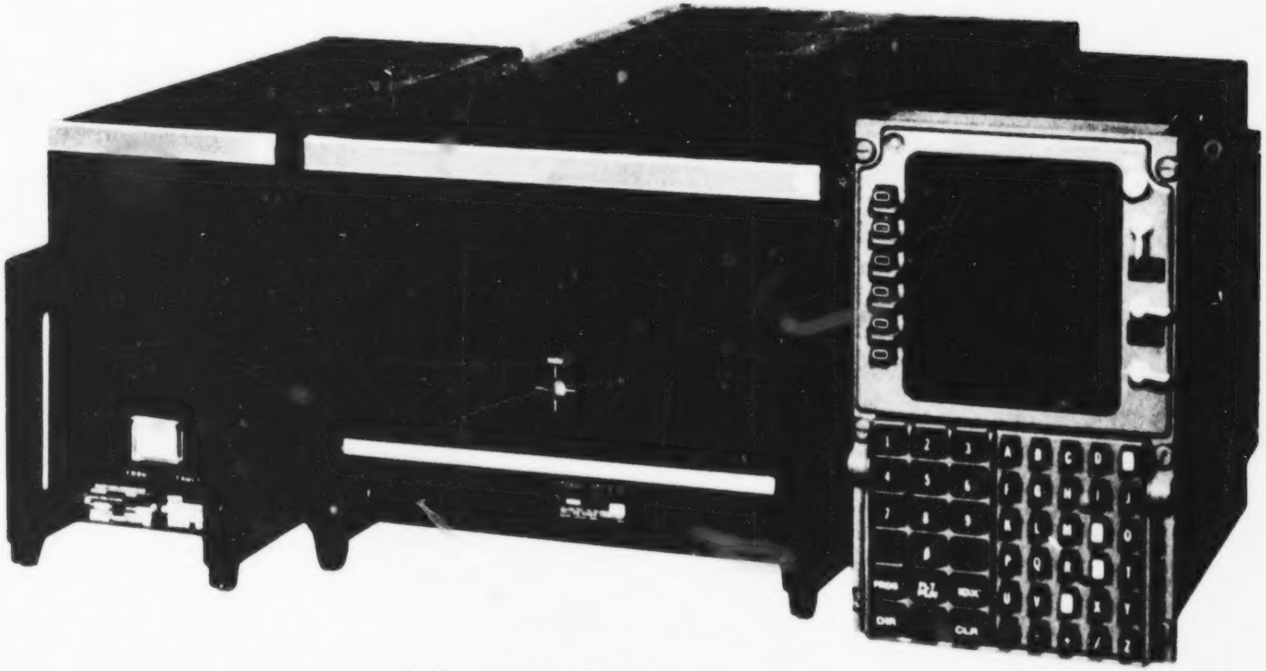
TWO-SEGMENT APPROACH
SWITCHING UNIT

TWO-SEGMENT APPROACH
CONTROLLER

SELECTOR SWITCH

FIGURE 4

AREA NAVIGATION SYSTEM COMPONENTS MODIFIED FOR TWO-SEGMENT NOISE ABATEMENT APPROACHES



FLIGHT DATA STORAGE UNIT
NAVIGATION COMPUTER UNIT
CONTROL DISPLAY UNIT

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FIGURE 5

Prior to actual flight tests, extensive flight simulator evaluations were conducted to assess, evaluate, and assure flight safety. Flight profile variations, operational abnormalities, and equipment malfunctions were simulated. Extensive engineering flight tests and guest pilot evaluations were conducted before initiating the in-service 727 flights by United Air Lines.

More than 600 two-segment approaches were flown, in the pre-service phase of the program, about 30 percent of them under instrument-flight weather conditions. Pilots from 12 airlines, NASA, and the FAA were involved.

The in-service evaluation commenced on the West Coast in April 1973, with two-segment approaches being made at Los Angeles, San Francisco, and Portland. The six-month evaluation was successfully completed on October 28, 1973.

Fifty-five United pilots participated, 555 two-segment approaches were flown without incident, and over 40,000 passengers were carried. The approaches were accomplished uneventfully by the flight crews and unnoticed by the passengers.

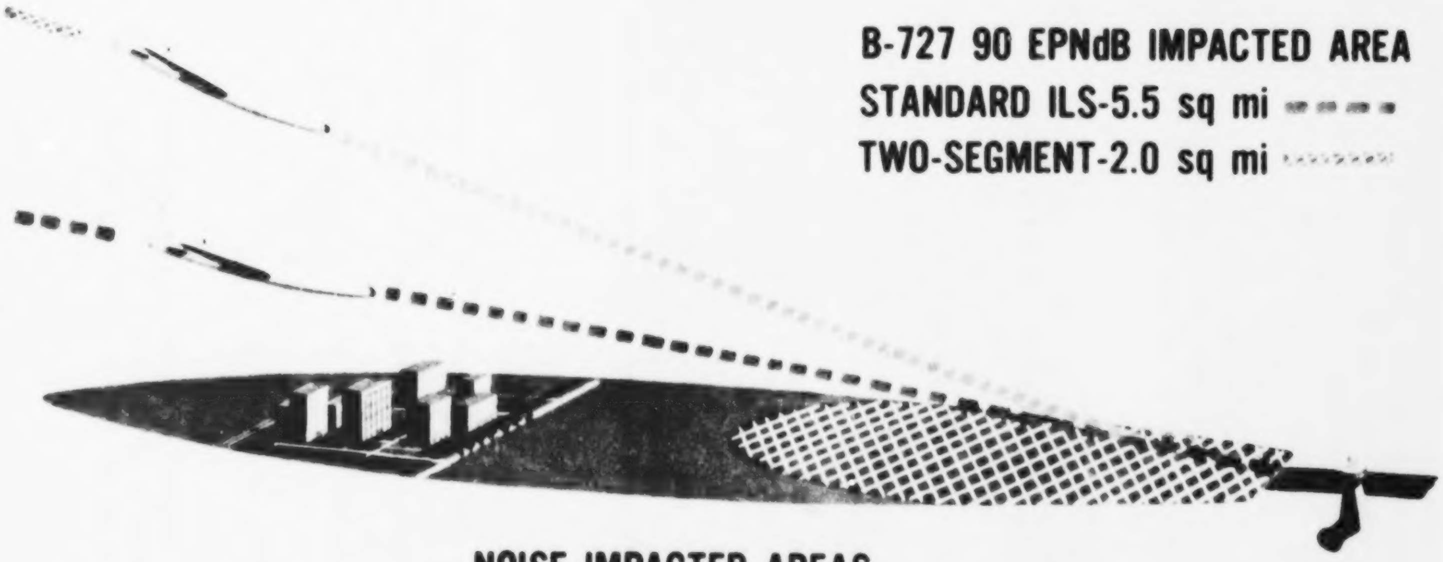
Figure 6 illustrates that the 727, using a two-segment approach, exposes 2.0 square miles of land to noise levels greater than 90 equivalent preceived noise, decibels (EPNdB), compared to 5.5 for a normal approach, a 64 percent reduction. The reduced power setting of the two-segment approach also saves a small amount of fuel, about ten gallons for a 727. An annual saving of about 50 million gallons of fuel would accrue if all U. S. carriers were making two-segment rather than conventional approaches.

DC-8 Two-Segment Approach Program

United Air Lines is now conducting an investigation of DC-8-61 two-segment approaches for NASA. It is considered the most challenging airplane for two-segment approaches because of its low drag in the landing configuration. Our tests have confirmed that the recommended upper segment of the DC-8 two-segment approach should be 5.5° rather than the 6° attainable with the 727. As shown in Figure 7 the DC-8 on a 5.5° two-segment approach exposes about 5.5 square miles to greater than 90 EPNdB, compared to 11.6 for a normal approach, a 53 percent reduction.

The modified area navigation system shown in Figure 5 is used to provide the two-segment approach guidance for the DC-8. This mechanization provides a low cost option for aircraft already equipped with an area navigation system.

NOISE RELIEF FROM TWO-SEGMENT APPROACH



B-727 90 EPNdB IMPACTED AREA
STANDARD ILS-5.5 sq mi ▬ ▬ ▬
TWO-SEGMENT-2.0 sq mi ▨

NOISE IMPACTED AREAS

FIGURE 6

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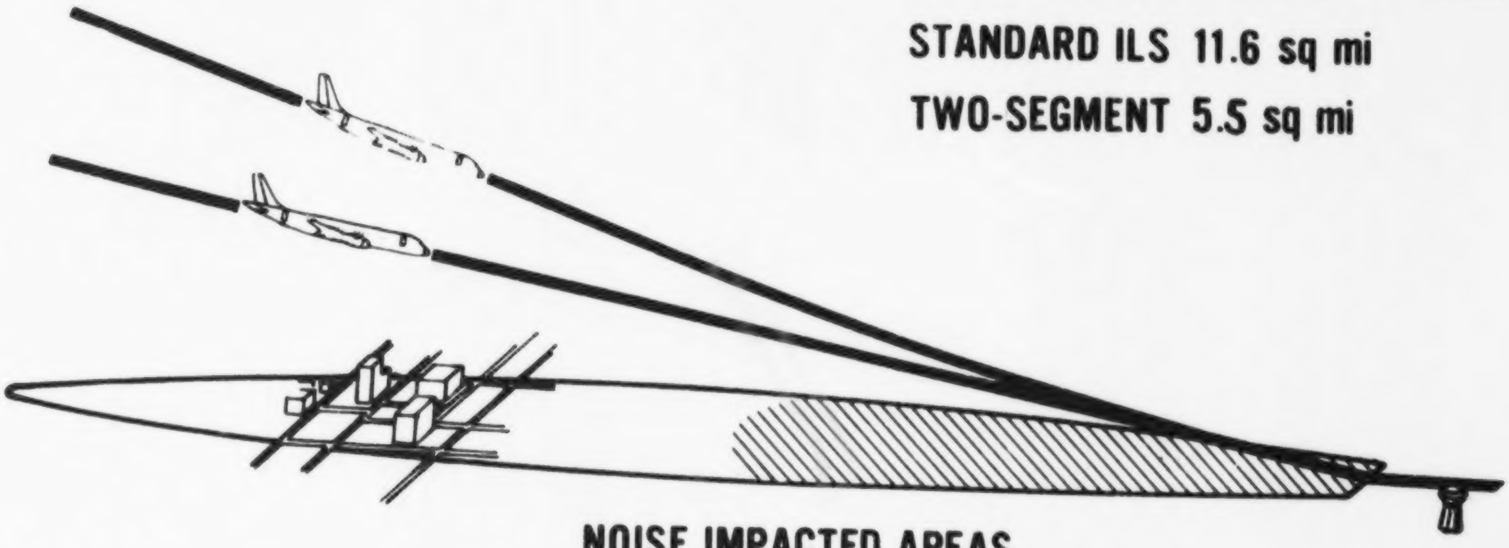
TWO-SEGMENT APPROACH

DC-8 90 EPNdB IMPACTED AREA

STANDARD ILS 11.6 sq mi

TWO-SEGMENT 5.5 sq mi



NOISE IMPACTED AREAS

FIGURE 7

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(Rev. 1) 12-27-73

In August, in-service evaluation of the DC-8 two-segment approach system will be initiated with line pilots. This will follow a three month engineering flight evaluation period. To date, nearly 800 DC-8 two-segment operational approaches have been made by United in the engineering flight evaluation period. Early reports indicate acceptance by the 45 (including 21 guest) pilots that participated in the program.

Applicability of the Two-Segment Approach to Other Aircraft

Analytical studies by the manufacturers have established the applicability of the two-segment approach to other aircraft in the civil jet transport fleet. Figure 8 summarizes the noise relief that would be expected. When these benefits are considered in proportion to the projected operations of the fleet for 1977, the area impacted by an approach noise level, of 90 EPNdB or greater, is estimated to be reduced by about 57 percent.

Wake Turbulence

One anticipated problem with the two-segment approach is the airplane's wake turbulence, which can cause an upset of a following airplane. With the two-segment approach, it has been postulated that a closely following aircraft might not be able to operate clear of the preceding airplane's trailing wake vortex as often as behind an airplane making a conventional straight-in approach.

Results of joint NASA/FAA flight tests have shown that the strength of the wake vortex generated on a two-segment approach is substantially the same as that generated from conventional approaches. Vortex settling characteristics also appeared to be about the same. The significance of these factors with regard to the spacing and other operating requirements for following aircraft are under study with the FAA. The FAA will use these data to help determine its position of the use of two-segment approaches for noise abatement.

Summary

In summary, as of July 1, 1974, nearly 2000 two-segment approaches have been conducted with 727 and DC-8 aircraft by about 170 pilots. Guest pilots have generally started their evaluations with an apprehensive, skeptical attitude toward the desirability, feasibility and acceptability of two-segment approaches. Typically, a guest pilot appeared to have the procedure in-hand by the third practice approach. With very few exceptions, by the end of their evaluation flights there was

APPROACH NOISE AREA REDUCTION POTENTIAL WITH THE TWO-SEGMENT APPROACH

AIRPLANE	REDUCTION IN 90 EPNdB IMPACTED AREA WITH TWO-SEGMENT APPROACH %	ESTIMATED OPERATIONS IN 1977 -%	FLEET-WEIGHTED REDUCTION IN 90 EPNdB IMPACTED AREA - %
B-707	57	9	57
B-727	64	40	
B-737	52	10	
B-747	39	5	
DC-8	53	5	
DC-9	63	18	
DC-10 / L-1011	44	13	

FIGURE 8

NASA RO74-2498
2-19-74

a nearly complete reversal of opinion, i.e., from opposed to cautious optimism and support. Acceptance of the concept by a pilot appeared to progress in proportion to the number of two-segment approaches flown.

The results of the Two-Segment Approach Program indicate that the technique is an operationally feasible and safe technique for providing a significant reduction in aircraft approach noise. A full understanding of the operational implications of wake turbulence for following aircraft remains to be developed.

AIRCRAFT NOISE PROGRAM COORDINATION

My following comments are directed to the Subcommittee's interest in the coordination of the Government's programs related to aircraft noise reduction.

NASA is continuing to work closely with DOT, FAA and EPA, at the staff level, through working panels, and through the Joint DOT/NASA Office of Noise Abatement, to help assure that the Government has an integrated research and technology program directed toward the near and longer term reduction of aircraft noise.

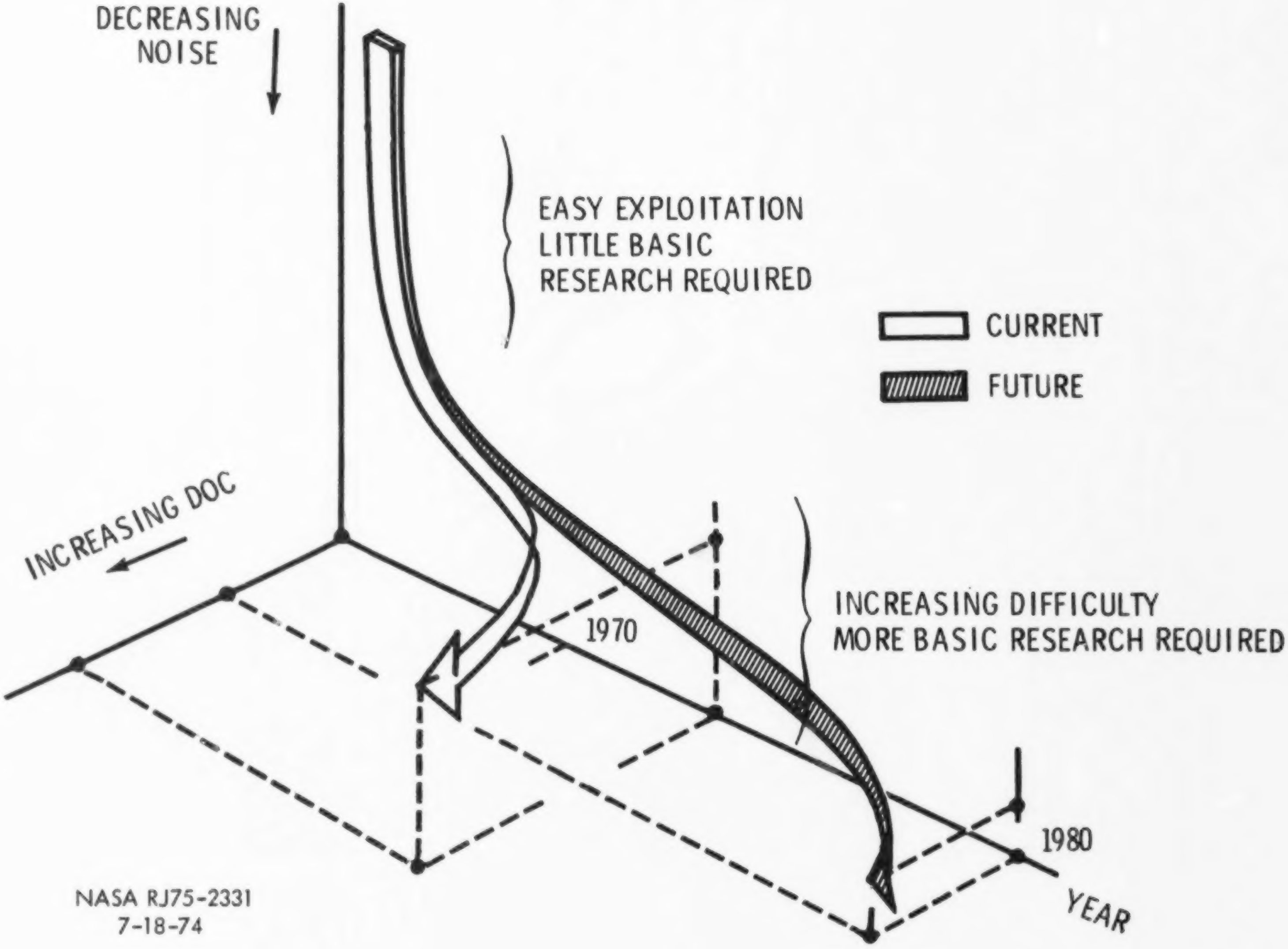
Through the Joint Office, we have provided EPA with our most recent internal program planning data and as members of their noise research and technology program coordination panels, we have met with them as late as this past month to assist in their coordination effort.

NASA AIRCRAFT NOISE REDUCTION ACTIVITY

We believe that NASA has made and is continuing to make progress in the development of technology for the reduction of aircraft noise. This progress is being achieved through research on the understanding, control and reduction of engine, aircraft and operations related noise. We are also vitally concerned with the reaction of people and communities to air transportation noise.

The Civil Aircraft Research and Development (CARD) policy study set a general goal for the reduction of aircraft noise of 10 dB per decade. Technologically, this goal is achievable in this decade. However, the prospects of achieving this goal in the next decade are reduced by the consideration of technical and practical operating costs. This situation is illustrated in Figure 9. For near term practical air transport designs, we believe designers will be able to reduce aircraft noise to conform to FAR-36 with little increase in direct operating costs (DOC). In the longer term it is not clear that we can achieve an additional 10 dB noise reduction without a significant and possibly unacceptable increase in DOC.

AIRCRAFT NOISE REDUCTION


DECREASING NOISE
EASY EXPLOITATION
LITTLE BASIC
RESEARCH REQUIRED
☐ CURRENT
▨ FUTURE
INCREASING DOC
1970
INCREASING DIFFICULTY
MORE BASIC RESEARCH REQUIRED
1980
YEAR

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7-18-74

FIGURE 9

We feel, however, that it is important for us to continue our efforts to reduce noise and maintain operating efficiency. Our longer term programs are directed toward these objectives. To illustrate, I will review selected efforts to provide for future noise reduction, improved noise prediction, and an understanding of the impact of noise on people. These programs include: advanced acoustic composite nacelles, airframe noise reduction, propeller noise reduction, aircraft noise prediction, and human response to noise.

Acoustic Composite Nacelles

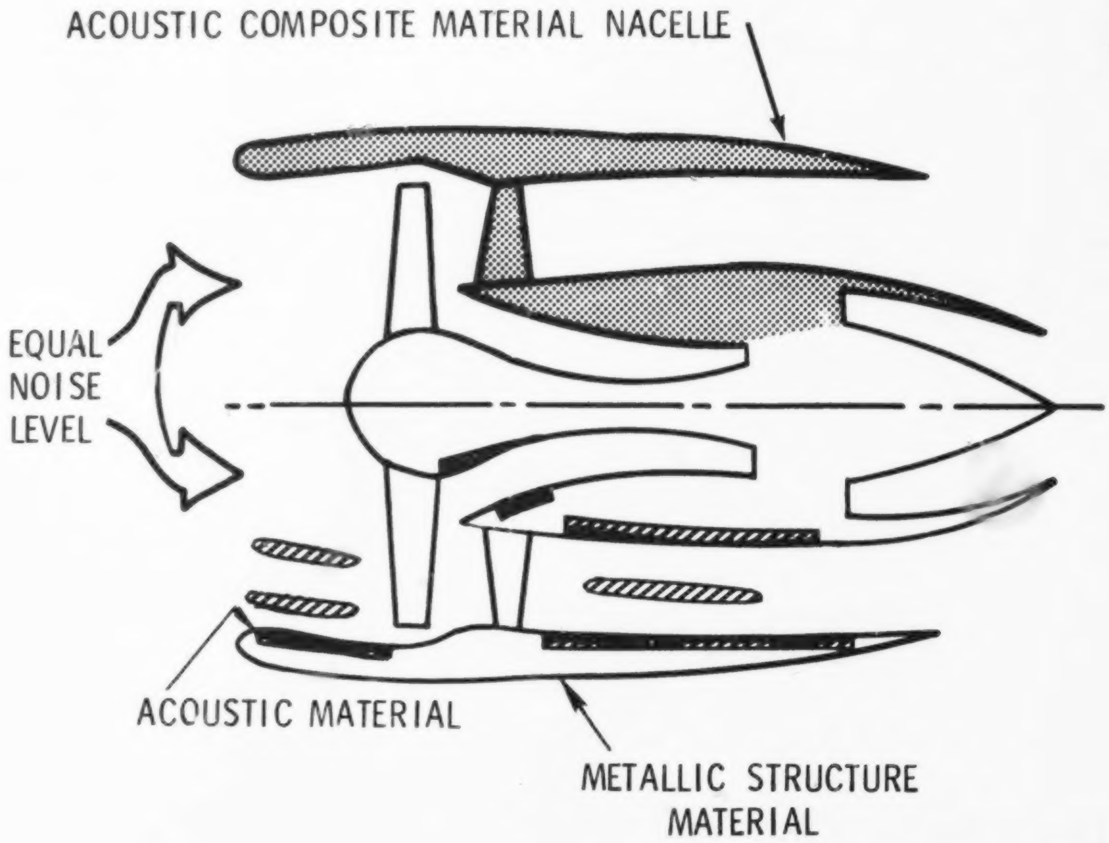
The acoustic composite nacelle program was developed to design and demonstrate light-weight nacelles constructed of integrated structural acoustical material. As shown in Figure 10, current nacelle noise reduction technology involves lining the nacelle with non-load-carrying sound absorption material. This reduces engine noise, but weight and fuel consumption are increased. We are exploring the use of advanced acoustic composite materials which interweave sound absorbent and structural materials to form a sound absorption structure. Laboratory studies indicate that for the same nacelle weight at 15 dB reduction in sound intensity may be possible through the use of acoustic composite structural material.

Conceptual design studies of such a nacelle were initiated in FY 1974. The findings from these studies will be verified through laboratory investigations during FY 1975, and nacelle designs will be initiated in FY 1976. We plan to complete ground tests in FY 1979.

The nacelle design will be appropriate for current wide-body transports so that after completion of ground testing (including flight-qualification tests) the nacelle could be demonstrated in flight. The potential value of this type of nacelle is shown in Figure 11. An acoustic composite nacelle applied, for example, to a future production DC-10 offers the performance potential of reducing the 90 EPNdB noise footprint area by an estimated 30% without a change in airplane weight or operating cost or, for the same noise performance (footprint), the aircraft weight could be reduced by about 2700 lbs., and 1000 lbs. of fuel could be saved on a transcontinental flight.

This technology, of course, is applicable to future advanced technology transports.

APPLICATION OF ACOUSTIC COMPOSITE STRUCTURAL MATERIAL


ACOUSTIC COMPOSITE MATERIAL NACELLE
EQUAL NOISE LEVEL
ACOUSTIC MATERIAL
METALLIC STRUCTURE MATERIAL

ADVANCED TECHNOLOGY

REDUCED:

- WEIGHT
- FUEL

CURRENT TECHNOLOGY

INCREASED:

- WEIGHT
- DRAG
- FUEL

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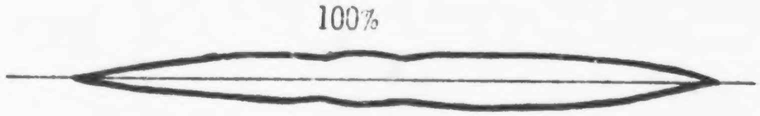
FIGURE 10

TYPICAL ACOUSTIC COMPOSITE NACELLE BENEFITS FOR A 3 ENGINE WIDE-BODY TRANSPORT

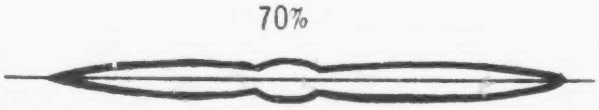
CURRENT AIRCRAFT

90 EPNdB NOISE FOOTPRINT



WITH APPLICATIONS OF ACOUSTIC COMPOSITE NACELLES

NO CHANGE IN WEIGHT AND FUEL



OR

2700# LESS WEIGHT
1000# LESS FUEL, TYPICAL TRANSCONTINENTAL FLIGHT

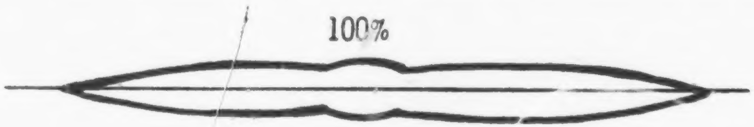


FIGURE 11

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Airframe Noise

A relatively new area of concern is airframe noise. Our concern stems from the fact that noise from landing gears, wings and flaps, body flow separation and tail surfaces is at levels about 8 to 10dB below the current FAR-36 requirement as illustrated in Figure 12. Because future conventional aircraft engine noise at landing may be reduced some 10 and possibly 15 EPNdB below FAR-36, airframe noise could become the factor limiting approach noise reduction.

The objectives of our airframe noise reduction program are to identify and quantify the sources of airframe noise, and to determine the principles and provide the data for minimizing this noise. A major part of the work will be accomplished through model studies of components in quiet wind tunnels and in the new Aircraft Noise Reduction Laboratory facilities at the Langley Research Center. Flight testing will continue to support development of data in this critical area. Special studies will be made to relate airframe noise measurements, made at model scale in wind tunnels, to full-scale flight test data.

Later phases of the effort will involve studies of noise generation and its control as related to advanced concepts for high lift devices, landing gears, other protuberances, and bodies and wings.

Propeller Noise Reduction

During testimony on General Aviation in March 1974, the Subcommittee expressed interest in what NASA was doing to improve propeller design to achieve better performance and reduce noise. We are approaching propeller noise from several aspects.

Under a grant to the University of Illinois, effort is being directed toward providing practical free-propeller design criteria to optimize planform, airfoil section, twist and camber for minimum noise and maximum efficiency. The effect of the supercritical airfoil section, on both noise and efficiency, as applied to propellers, is also under study. Flight tests of these propellers will be carried out in conjunction with the Advanced Technology Light Twin (ATLIT) Program during the second and third quarter of FY 1975.

Noise reduction potential and thrust efficiency of shrouded propellers are under study. Full scale wind tunnel tests of a modified Cessna 327 incorporating an aft propeller shroud were completed this month. Reduction of the data is underway and will provide the basis for decisions on the feasibility of a subsequent flight demonstration program.

SIGNIFICANCE OF AIRFRAME NOISE

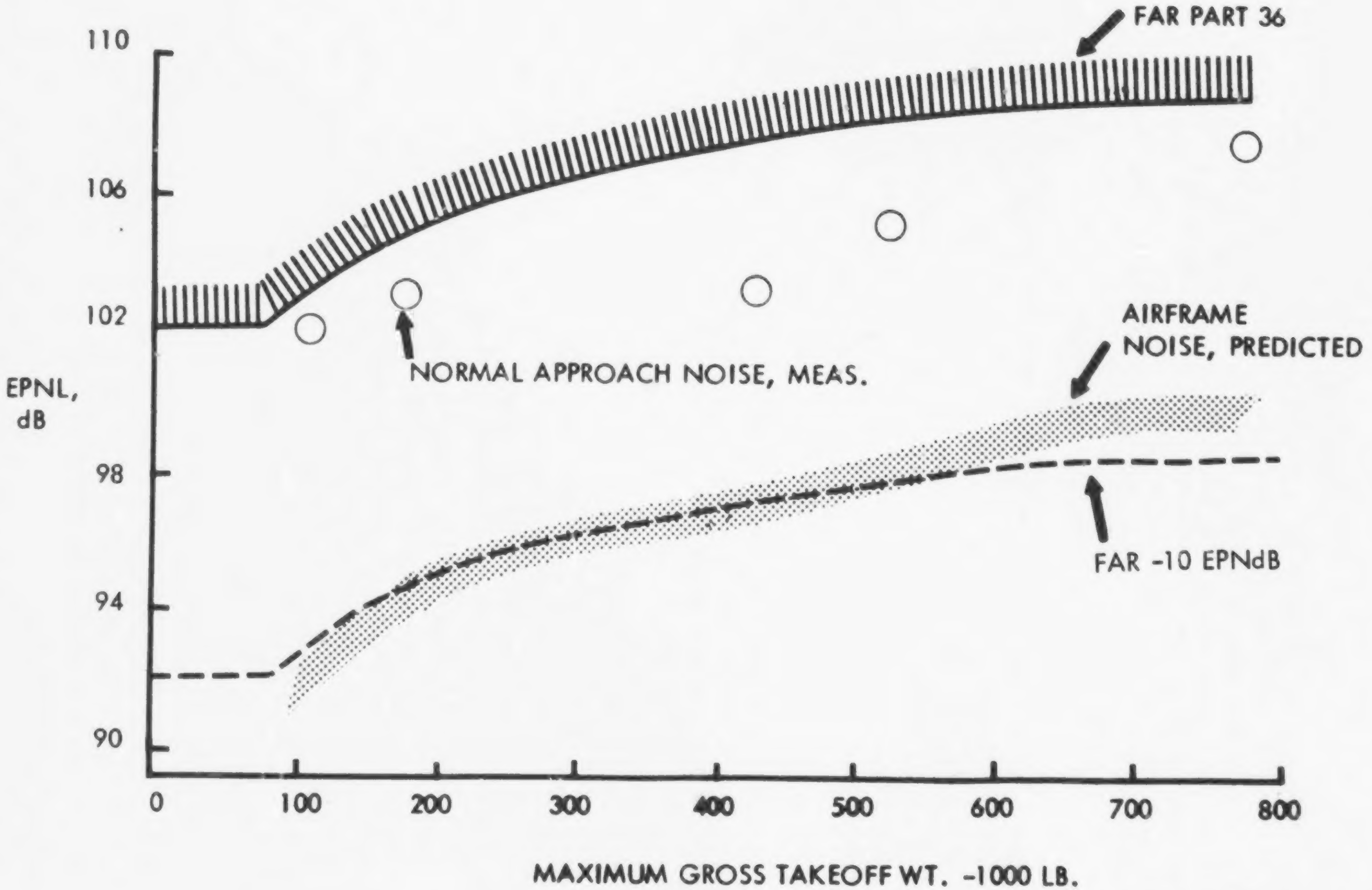

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FIGURE 12

The same Cessna 327 will be modified to incorporate a Hamilton Standard "Quiet-Fan" (Q-fan) turbofan engine. Although the Q-fan is expected to be an expensive system, the noise reduction potential is great. Full scale wind tunnel tests of the modified airplane, in mid-1975, will provide a basis for further studies or flight programs.

Aircraft Noise Prediction

Our concern with the design of aircraft for minimum noise generation or to specific noise standards led to the establishment of an Aircraft Noise Prediction Office at our Langley Research Center this past year. The Office with support from other NASA centers, will develop computational techniques for accurate prediction of operating aircraft noise levels as perceived on the ground. This capability is essential for assessing the noise characteristics of aircraft: new designs, aircraft modifications, proposed noise abatement operational procedures, as well as the impact of future air transportation systems on airport communities.

The prediction capability will also provide a basis for identifying noise reduction technology goals and research needs related to aircraft components, aircraft design, and airport operations. It will assist Federal agencies in future rulemaking and regulatory activities, airport planners in airport development, and airport communities in land use planning.

Response to Aircraft Noise

The last subject I will comment upon is human response to aircraft noise. During the FY 1975 authorization hearings, reference was made to such a study completed at Columbia University. In this research program the range of noise reduction proposed for retrofits for the 727 airplane was simulated. Figure 13 summarizes the results of the investigation. An annoyance number of 4 is very annoying. A number of 0 is not annoying. A reduction of 6 EPNdB represents the level of noise reduction under the landing approach path expected for the SAM and anticipated for the refan retrofits for the 727 airplane. From these test results we conclude that under laboratory conditions significant reductions in annoyance can be realized by a 6 EPNdB noise reduction. In the Columbia study at the 1.1 mile approach point for the untreated airplane, 72 percent of the subjects were highly annoyed; for the -6 EPNdB case, 34 percent of the subjects were highly annoyed; and for the -12 EPNdB case, 16 percent were highly annoyed.

SUBJECTS' RESPONSE TO SIMULATED AIRCRAFT OPERATIONS
COLUMBIA UNIVERSITY STUDY

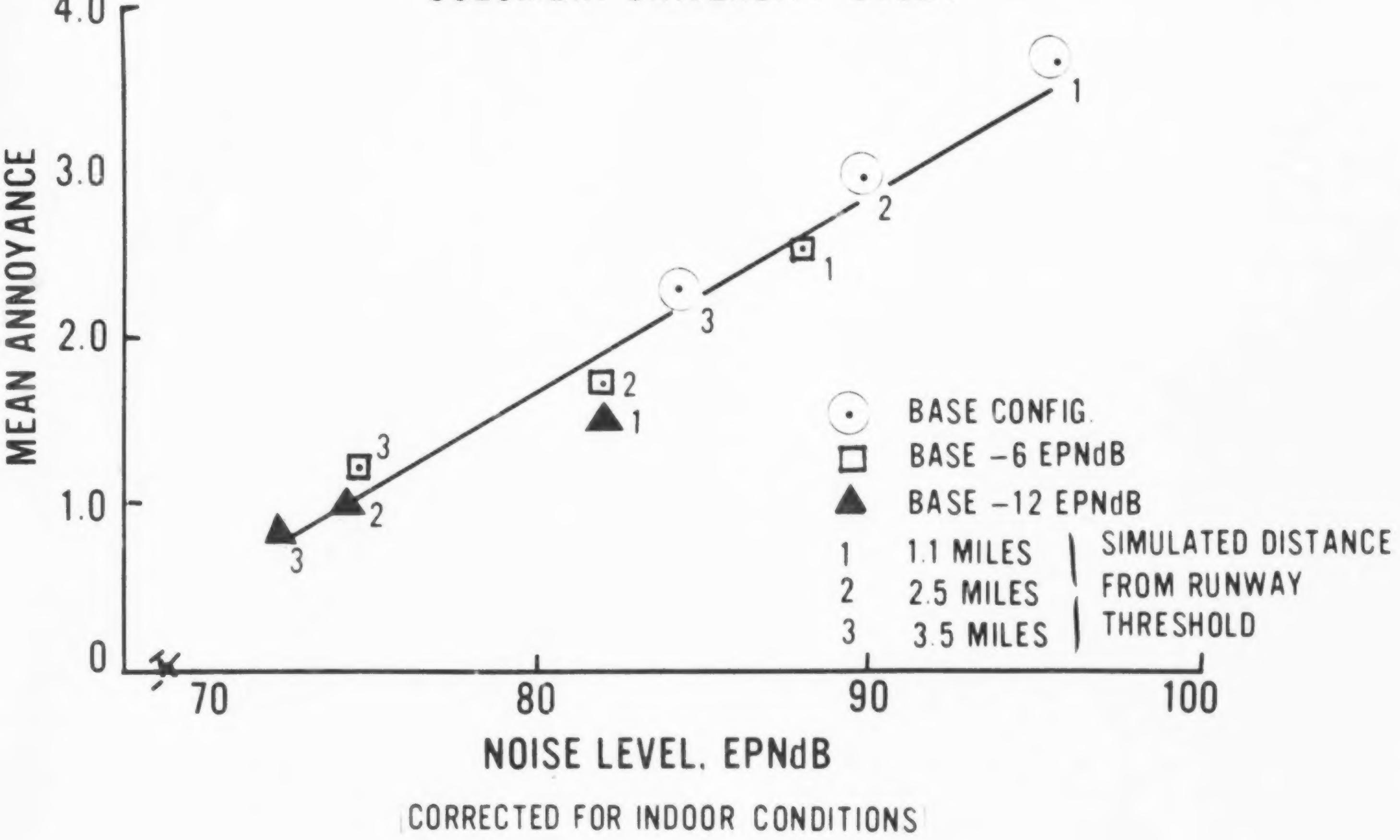

FIGURE 13

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We believe that the experimental tools developed in this program provide a useful technique for the study of the annoyance of aircraft noise.

The Columbia study initially was limited to one aircraft type and to the landing condition, but has been extended to consider several aircraft types for both landing and takeoff. The results of the extended investigation should be available early this fall. More detailed experiments are being planned for the Aircraft Noise Reduction Laboratory at Langley. These studies will complement those underway at Columbia and will assess both the effects of different mixes of aircraft and different rates of noise exposure.

Attention is also to be given to resolving the differences in the responses to aircraft noise of various population sub-groups. This information should provide a basis for the definition of more acceptable noise environments for airport communities.

Closing

We believe that our program will provide the data base needed for near and longer term action by industry, the public, and responsible government groups to evolve toward a more compatible airport community noise environment. We will continue to work closely with the responsible government groups, DOT, FAA and EPA to help bring into practical realization the fruit of our research and technology.

2. NASA

BASIC RESEARCH
AND
TECHNOLOGY
PROGRAMS

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OBJECTIVE DOCUMENTATION

Title: Propulsion Noise Reduction

Type of Specific Objective

_X_ Discipline ___ Study___ System and Experimental Program

Organizational Element Responsibility:

Noise and Pollution Reduction Branch - Harry W. Johnson (Act.)

Statement of Specific Objective and Targets:

Objective: To provide data and a technology base for reducing aircraft propulsion generated noise with minimum weight, performance and economic penalties. Specific targets are:

- Obtain experimental and analytical data for a more accurate understanding of noise generating mechanisms in simple jet flows which can be used to guide the technology for reducing jet noise generation. FY 1976 for subsonic jets; FY 1978 for supersonic jets.
- Reduce by 60% the currently achievable thrust loss penalty due to supersonic jet noise suppression devices to 1% per 5 EPNdB. FY 1977.
- Determine the basic effects of forward velocity on jet noise generation and propagation. FY 1977.
- Achieve 4 to 6 EPNdB reduction in fan-stage source noise (relative to Quiet Engine I fan technology levels) by means of aeroacoustic design. FY 1977.
- Improve the efficiency of acoustic suppression materials and technology to achieve, for a given dB reduction, a 50% reduction (relative to 1974 design practice) in the installation weight attributable to such suppression treatment. FY 1977.
- Demonstrate practical (high subsonic throat Mach number inlet design concepts to achieve 20 EPNdB suppression of forward radiated fan noise without increasing aft radiated noise nor introducting

undesirable engine performance, stability and operating condition limitations. FY 1977.

- Determine the noise generation or suppression effects due to internal and external surfaces which guide or control jet flows, including effects of shielding and surface treatment. FY 1977.

- Determine the mechanisms responsible for noise emanating from core noise sources (combustors, struts, turbines) and establish practical techniques for controlling these noise sources to optimize acoustic designs of propulsion systems. FY 1978.

- Establish the effects of the random characteristics of the atmosphere on the propagation of aircraft noise into the airport community. FY 1977.

Approach:

Propulsion noise reduction aims at providing a technology base and data for the understanding and reduction of aircraft propulsion component and system generated noise with minimum weight, performance and economic penalties. The program at Lewis Research Center is directed at fundamental studies of turbo-machinery, jet and jet interaction. Experimental studies will continue on sonic inlets, fans, nozzles, core suppression and wing shielding including tests using Quiet Engines A and C. The program at Langley Research Center emphasizes fundamental studies of component and jet noise and the effects of atmospheric conditions of sound propagation. The aircraft Noise Reduction Laboratory, completed in early 1974, is the focal point for Langley in-house research and complementary university acoustic research activities. The programs at Ames Research Center will include wind tunnel tests to measure forward velocity effects. Aircraft static and flyover noise measurements will be made at Flight Research Center. The Jet Propulsion Laboratory conducts research on high temperature supersonic velocity jet noise and the correlation of different noise measurement instrumentation techniques now in use. Major milestones for Propulsion Noise Reduction are:

- FY 1975 - Demonstrate J-85 noise suppression using a retractable nozzle in F-106 flight tests.

- Early FY 1975 - Complete exploratory studies of noise propagation and atmospheric attenuation using an instrumental tower.

- Mid FY 1975 - Complete flight test noise measurements on supercritical propeller design.
- Early FY 1976 - Conduct wind tunnel noise tests on variable pitch Q-Fan for General Aviation Aircraft.

Need and Relevancy:

Aircraft noise is a major constraint to the growth of civil aviation, and has become a major target for environmental improvement. The NASA noise reduction program is intended to provide the technology for reducing aircraft noise ultimately to levels which communities will find acceptable, and to do so in a manner that permits aircraft operations to remain economically viable.

OBJECTIVE DOCUMENTATION

Title: Noise Footprint Prediction

Type of Specific Objective

_X_ Discipline ___Study ___System and Experimental Program

Organizational Element Responsibility:

Noise and Pollution Reduction Branch - Harry W. Johnson (Act.)

Statement of Specific Objective and Targets

Objective: To establish techniques for accurate prediction of ground noise levels of operating and future aircraft to establish total acoustic characteristics, identify parameter sensitivities, and guide research efforts. Specific targets are:

- Select and construct an interim computer program for noise contour predictions by FY 1975.
- Improve the data base capabilities of the interim program to predict noise contours (footprint areas) within ± 40 percent accuracy (± 1.5 dB accuracy of noise contour). FY 1976.

- Establish a prediction and design capability to compute noise contours for current and proposed aircraft systems based on analytical modeling of individual component noise sources. FY 1978.

Approach

The Noise Footprint Prediction program at Langley Research Center, with specific support by the other centers, will evolve computational techniques for accurate prediction of ground noise levels from operating aircraft to establish acoustic characteristics, identify parameter sensitivities and guide research efforts.

Major milestones of the Noise Footprint prediction research are:

- By FY 1975 - Establish interim aircraft noise prediction program.
- Mid FY 1975 - Establish basic analytical models for key technical areas in source noise prediction, noise transmission, and community impact.
- Late FY 1975 - First results from the integrated noise prediction program.

Need and Relevancy

Demands imposed on jet aircraft by recent noise regulations have emphasized the need for an accurate noise footprint prediction capability. This capability is essential not only for evaluating the effect of proposed noise abatement procedures and aircraft modifications, but also for evaluating the impact of future aircraft systems on airport communities. The prediction capability will provide a basis for establishing noise reduction technology goals and identifying research needs in the areas of components, aircraft designs, and airport operations. In addition, the prediction program will assist other federal agencies in future rulemaking and regulatory activities, and will aid airport communities in land use planning.

OBJECTIVE DOCUMENTATION

Title: Minimization of Undesirable Aerodynamic Phenomena

Type of Specific Objective

_XX_ Discipline ____ Study ____ System and Experimental Program

Organizational Element Responsibility

Aerodynamics & Vehicle Systems Division - Alfred Gessow

Statement of Specific Objective and Targets

Objective: To understand, and minimize by aerodynamic means, the undesirable effects of aerodynamic phenomena such as wake vortex turbulence, aircraft buffeting and airframe noise. Specific targets are:

- Determine by January 1974 one or more aerodynamic techniques which show promise of effectively eliminating the wake vortex hazard in order to provide FAA with information with which to set potential requirements for operational vortex detection and tracking systems at airports for safe spacing of aircraft during landing and takeoff.

- Demonstrate in flight by FY 1977 aerodynamic design techniques which would permit a reduction from the present 3-5 mile landing separation distance imposed on transport aircraft by the wake vortex problem to two miles.

- Determine the design principles and provide the necessary data on airframe (i.e. nonpropulsive) noise to insure that the CARD policy study goal of reducing aircraft noise by 10 dB per decade can be achieved. The technology required for the first 5 dB reduction to be in hand by FY 1977.

- Using unsteady pressure distributions measured on wing sections in wind tunnels, provide a means for predicting the intensity of the buffet phenomenon of combat aircraft throughout their maneuver range by mid FY 1975. With such predictive capability, not currently available, provide the design information necessary to extend the buffet boundary of combat aircraft by approximately 100% by FY 1977 and thus provide the potential for the development of new aircraft with greater operational capability in combat situations.

Approach

Aerodynamic factors that control the generation and magnitude of wake vortex, aerodynamic noise, and aircraft buffet phenomena will be studied to determine the means by which the detrimental effects can be reduced or eliminated.

- The airframe noise (i.e. the noise generated by an aircraft in flight with its propulsion system noise subtracted out) program effort will be concentrated on determining the source, magnitude, and method of reducing such noise for large transport aircraft in the clean and approach (i.e., flaps and landing extended) configurations. The individual noise contributions of high-lift devices, separated flow associated with the landing gear, gear-well cavity flow, and flaps will be investigated. The program will be conducted with LRC as the lead Center, aided by flight research at FRC, and supporting wind tunnel and basic research at ARC and JPL. Basic noise source measurements will be made in conventional and quiet wind tunnels and anechoic chambers with simple wings and configurations to establish the feasibility and test techniques for these types of measurements in inherently "noisy" ground facilities. Airframe noise prediction techniques will be developed using fundamental noise source principals and data correlations. Far field aerodynamic noise measurements from flight tests of jet transport aircraft will be compared with predicted noise levels and corresponding measurements from wind tunnel tests of scaled transport models for verification of the ground test techniques. Aerodynamic design concepts for minimizing airframe noise will then be defined from analytical prediction techniques, developed in ground facilities and demonstrated in flight tests.

- The wake vortex hazard alleviation program will be conducted at ARC, LRC, and FRC and will include a vigorous ground research effort with preliminary flight tests to develop promising alleviation devices, and measure detailed vortex structure. The development of promising vortex alleviation devices or concepts will require investigations planned to be conducted in contractor water channels, NASA ground facilities and in flight. The effectiveness of such aerodynamic devices or concepts as spoilers, trailing drag devices (splines), vortex generators steady and pulsed mass injection, and tailored span load distributions will be investigated. Ground facility measurements to evaluate the effectiveness of the alleviation devices include documenting the vortex-induced rolling moment imposed on trailing aircraft models, positioned at scaled distances up to about 1½ miles downstream of the generating aircraft models. In addition, hot-wire probes and LDV instrumentation will be further developed for obtaining vortex tangential and axial velocity and core growth measurements. Based on preliminary results from the on-going ground research program, aerodynamic devices or techniques which show promise of significantly reducing the wake vortex strength include deployment of spoilers and splines, and tailored span loading to achieve a triangular-like lift distribution. Plans are to intensify the ground research effort to further refine and develop those aerodynamic devices, and to verify and demonstrate the most promising devices in flight tests using existing NASA aircraft initially and to later lease a wide body jet transport for final demonstration.

- The buffet program will be conducted at ARC in the Ames transonic unitary tunnel complex and will be supported by contractor flight studies and analyses. Correlations will be made of measured and calculated buffet alleviation techniques--supercritical wings, flaps, etc.--will be studied. Locations of shock waves and flow separation will be identified, and studies of unsteady pressures and forces will be made. Predictions of aircraft structural response characteristics during buffet will be developed to assess the effects of buffet on aircraft design loads.

Major Milestones of the Minimization of Undersirable Aerodynamic Phenomena Program are:

Late FY 1974 - Select candidate vortex minimization devices or concepts for flight test evaluation.

Mid FY 1975 - Begin flight test evaluation and demonstration of promising vortex alleviation devices.

Mid FY 1975 - Identify individual airframe noise source contributions on jet transport.

Mid FY 1975 - Develop analytical prediction techniques for radiated aerodynamic noise from discrete sources.

Mid FY 1975 - Develop capability to predict buffet intensity of combat aircraft throughout maneuver envelope.

Mid FY 1976 - Initiate final flight demonstration with most effective vortex alleviation devices on wide-body jet transport.

Need and Relevancy

The persistent nature of trailing vortices generated by jet transports creates a documented safety hazard for closely following aircraft and severely curtails optimum use of our nations airports. FAA has taken action to deal with the problem by increasing approach and takeoff separation distances to 5 miles (from 3 miles) for smaller aircraft following a wide-body aircraft. This is not a satisfactory long term solution because of the greatly reduced runway utilization rate, particularly in view of the heavier jet transports and increased traffic volume projected for the future. Also, the increased separation distances cause ground holding delays prior to takeoff and in-flight holding delays prior to landing during peak traffic periods which waste precious fuel. Additionally, a major NASA/FAA goal aimed at relieving air traffic congestion involves as one facet the development and implementation of a sophisticated, accurate airport-located aircraft tracking system to allow less separation than presently employed. This will not be possible as long as the wake vortex hazard continues to define the minimum separation. The wake vortex hazard research program will attempt to reduce the present 3-5 mile separation distance to two miles.

A major CARD policy study goal concerns the reduction of aircraft noise by 10 dB per decade. Toward this goal, engine quieting efforts are achieving significant progress. However, recent measurements of jet transport aerodynamic noise during approach (engines throttled back) indicate that the noise level associated with the airframe is significant (only 10 dB below the FAR PART 36 guideline). Therefore, to realize full benefits from engine quieting efforts and to ensure that the CARD policy study goal can be achieved beyond the first step, airframe noise must be reduced below its current high level.

Buffeting and buffet induced roll instability at high angles of attack seriously restrict transonic maneuverability of military aircraft in the high subsonic speed range where aerial combat takes place. Consequently, to improve odds for victory, buffeting effects must be reduced to widen the combat envelope of military fighters.

OBJECTIVE DOCUMENTATION

Title: Acceptance of Aircraft Operations

Type of Specific Objective

_X_ Discipline ___ Study ___ System and Experimental Program

Organizational Element Responsibility

Aeronautical Man-Vehicle Technology Division - R. P. Whitten

Statement of Specific Objective and Targets

Objective: To define and quantify those properties of aircraft noise exposure that are responsible for causing negative individual and community response to air transportation systems. Specific targets are below:

- Devise proper methodologies for laboratory and field studies of human response to aircraft operations. FY 1975.
- Determine effects of multievent noise exposure characteristics on human response to aircraft operations. FY 1976.
- Quantify the effects of background environmental noise exposure on the human response to aircraft-generated noise. FY 1977.
- Ascertain the effects of aircraft noise on man's speech production/perception. FY 1977.
- Evaluate the effects of aircraft operations on sleep, relaxation and subsequent performance of people. FY 1978.

- Study the effects of low frequency noise characteristics generated by present and future aircraft on auditory and nonauditory responses of people. FY 1979.

- Develop a model for reliable prediction of responses of people to aircraft operations that will satisfy laboratory and field conditions. FY 1980.

Approach

Research on the psychophysiological response of humans to aircraft operations will be conducted primarily in the new Aircraft Noise Reduction Laboratory at the Langley Research Center. Sociopolitical impact analysis of new aviation technology will be conducted by the Ames Research Center.

- Develop a model that will scientifically explain the composite response of man to aircraft noise. As identified by the model, improve and/or develop those methods essential to the conduct of meaningful laboratory studies which simulate the impact of aircraft operations on the community: Verify the model and the methods developed for simulation studies by several field studies.

- Obtain data and record it in such a manner that it can be used for NASA data bank utilization, and for other federal agencies, i.e., DOT/FAA, EPA.

- Design simulation and field studies with a view towards correlation with specific characteristics of earlier studies so that proper interpretation and extrapolation of results can be made.

Need and Relevancy

Information to provide criteria for the prediction of community acceptance of aircraft operations by people living in communities near airports is of major importance in the development of noise control technology and operational procedures for civil aviation. The physical characteristics of noise and its propagation are fairly well understood; however, scientific data permitting an understanding of the impact of aircraft operations and noise on the community are sparse. Comprehensive scientific information on the psychophysiological effects of aircraft operations and noise is needed to assure the acceptability and effectiveness of programs designed to alleviate adverse community response to the air transportation system.

Because community research is time consuming and expensive, there exists a need to simulate the real world in a laboratory environment in such a manner that the laboratory results can be directly related to the operational world. The benefit of this capability is seen in the savings of resources and the ability to synthesize operations of future aircraft systems and then evaluate the degree of acceptance by the airport communities. To achieve this degree of sophistication, further development is needed in the area of subjective testing methodology to modify existing or develop new measurement scales. Such scales must be adequate to properly evaluate responses of people during both awake and sleep and for indoor and outdoor background noise. There is a special significance of current research in this area to the programs on advanced aircraft whose low frequency noise and impulse noise characteristics are not characterized adequately by existing measures of human response.

Today there exists a climate of general public hostility towards large visible technologies. A thorough understanding of this social attitude is needed to allow for accurate economic projections of future aircraft systems prior to system development. Development of such understanding would aid in the planning process of integrating a new system into an existing system.

OBJECTIVE DOCUMENTATION

Title: Advanced Powered-Lift Aircraft Aerodynamic Technology

Type of Specific Objective

XX Discipline ____ Study ____ System and Experimental Program

Organizational Element Responsibility

Aerodynamics & Vehicle Systems Division - John M. Klineberg

Statement of Specific Objective and Targets

Objective: To develop the aerodynamics and vehicle systems technology needed to attain the integrated aerodynamic performance, noise, stability, control, and handling qualities characteristics required for viable powered-lift civil and military aircraft designs having overall aircraft performance and flight characteristics compatible with operational approach CL's of about 4.5, 90 EPNdB noise, footprint less than 1 sq. mile, and direct operating costs not more than 10% above good CTOL transports. Specific targets are:

- Aero/Acoustic Exploratory Research - Provide, by 1975, first-order trade-off information on low-speed aerodynamic performance and noise for augmentor wing (AW) flap systems (including the use of break-up nozzles and thrust reversers) and for upper surface blowing (USB) concepts.

- Cruise Drag - Provide, by 1976, first-order trade-off information to avoid or reduce by half cruise drag penalties of upper surface blowing systems, indicated for preliminary analysis to be as great as 10% of total drag.

- Large-Scale Aero/Acoustic Verification - Verify the integrated aerodynamic noise, stability and control characteristics of representative complete powered-lift transport configurations models incorporating lobe-nozzle AW concepts by 1975 and USB concepts by 1976. Advanced systems with improved nozzles and augmented jet flap designs, will be verified by 1978.

- Handling Qualities and Control Systems - Evaluate the handling qualities requirements and promising methods of integrating vehicle aerodynamic and propulsion controls for powered-lift transports to enable precise flight path and airspeed control during low-speed terminal-area operation. Result will be the definition of tentative handling qualities design criteria and

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specific control system concepts by 1975. Also evaluate by 1976 a hinged plate spoiler system for improving flight path control and landing dispersion of a low wing loading nonpowered-lift STOL transport.

- Certification Criteria - Define tentative handling qualities and performance criteria necessary to serve as the basis for establishing airworthiness standards and define procedures for demonstrating compliance with standards. Targets for initial evaluation of individual system concepts are:

	CY
Deflected slipstream	1973
Augmentor Wing	1974
Externally blown flap	1974

Approach

The powered-lift STOL/RTOL aerodynamic programs are conducted at the Ames and Langley Research Centers. Effort at Ames emphasizes large-scale wing and model performance and noise tests in the 40- x 80-foot tunnel, primarily on the augmentor-wing and upper-surface blown flap concepts; related contracted analytical and experimental studies; and ground-based motion-simulator flight dynamics investigations. Langley performance, noise and handling qualities studies are concentrated on the upper-surface blown flap, involving use of theoretical analyses, small-scale and large-scale wind tunnel models, static rigs, and ground-based simulators. The specific approaches for accomplishing each of the identified targets follow:

- Aero/Acoustic Exploratory Research - Ames, in FY 1975, will conduct diagnostic experimental small-scale tests in the 7- x 10-foot tunnel and sponsor contractual investigations of advanced AW flap concepts to develop fundamental performance, acoustic, and thrust reversal technology for first-order design trade-off analyses for systems having superior terminal area performance and noise. This will include short-element flap systems. Langley will conduct small-scale and free-flight model parametric investigations to improve performance, stability and control characteristics of USB configurations which utilize the wing for noise shielding; will investigate fundamentals of USB noise on a static rig with engine exhaust directed through USB type nozzles over flaps; and will conduct some USB performance/noise trade-off design studies. Langley will also complete a series of experimental studies to establish reliable tunnel-wall corrections for powered-lift systems being experimentally investigated at high-lift conditions, and will continue powered-lift theoretical studies to devise improved flow and performance prediction methods. Ames will complete an investigation of turbulent mixing within AW multi-element nozzles to guide improved nozzle designs.

- Cruise Drag - Langley will perform parametric small-scale wind tunnel evaluations and analyses to develop by FY 1976 an adequate understanding of how to reduce cruise penalties accruing from USB installations. Ames will complete by FY 1975 a contractual small-scale study to develop cruise augmentor technology.

- Large-Scale Aero/Acoustic Verification - On a new semispan swept wing powered-lift model, Ames in FY 1975 on the static test rig and in the 40- x 80-foot tunnel will (1) complete the initial evaluation of an Ames-designed AW concept utilizing advanced multi-element lobe nozzles, (2) initiate evaluation of a Boeing cruise augmentor concept, and (3) initiate evaluation of a hypermixing ejector flap concept. This research model will be utilized for several large-scale verification tests of dirrerent powered-lift systems over a 3-5 year period. Langley will complete the initial static and low-speed noise and performance evaluations of a large-scale USB model (modified Aerocommander) in FY 1975, using the full-scale tunnel and the lunar-landing facility (for some of the noise measurements). A large-scale swept-wing USB model will be investigated in the Ames 40- x 80-foot tunnel. These large scale investigations as a whole are required to verify the integrated aerodynamic, propulsive, acoustic and structural dynamics characteristics and to provide valid data for design proposals.

- Handling Qualities and Control Systems - Ames, in FY 1975, will conduct handling-qualities investigations of representative powered-lift STOL/RTOL transports using ground-based simulators such as the FSAA, to provide solution to problems related to flight-path control and of the transition from cruise to approach. Ames, also in a joint program with the FAA, will conduct flight evaluations of a hinged-plate spoiler system integrated into the pilot's controls to augment flight path and roll control of a DHC-6 low-wing-loading nonpowered-lift aircraft. These evaluations under STOL operational conditions will investigate certification implications.

- Certification Criteria - In a joint program with the FAA, Ames in FY 1975 will perform studies on the FSAA in-house and under contract to provide additional criteria for establishing handling-qualities and performance certification standards for future STOL/RTOL powered-lift civil transports. Tentative criteria will be developed for aircraft using several of the more promising powered-lift concepts, contributing to a generalized criteria applicable to all concepts. Consideration will also be given to the development of safe flight procedures for demonstrating compliance with the criteria.

Need and Relevancy

The Joint DOT/NASA Civil Aviation Research and Development (CARD) Policy Study stressed the urgent requirement to reduce aircraft noise, to reduce congestion at airport terminals and to evaluate efficient, quiet short-haul transportation systems as a means towards such ends. Only 10 percent of the Nation's airports can accommodate today's jet transports requiring runway lengths of 5,000 feet or longer. Aircraft with operationally usable approach C_L's of about 4.5 capable of operating from 2,000 foot runways could be accommodated by 75 percent of the Nation's airports, and thereby offer tremendous congestion relief for some currently overcrowded airports. Such aircraft could also help congestion relief by operating from short new runways within existing major terminal hubs.

The achievement of this performance in aircraft having acceptable ride qualities and noise characteristics for the general riding and airport community public requires the use of efficient, quiet, powered-lift to provide useable approach lift coefficients up to 5 with noise levels not exceeding 90 EPNdB over a 1 square mile footprint. The research and technology efforts in this program are geared toward improving, evaluating and validating the aerodynamic and noise characteristics of advanced powered-lift concepts having promise of attaining the stated overall aircraft performance and noise goals as a part of the national effort to establish a high-density short-haul air transportation system.

C-8 AUGMENTOR WING FLIGHT EXPERIMENT

(766-71) Ongoing

Program Objective

Validate in flight the augmentor-wing powered-lift concept developed in laboratory programs as a practical means for providing short take-off and landing capability (under 2,000 foot balanced runway length) to alleviate terminal area congestion problems. Assess in flight the handling qualities of this type of aircraft. Provide a versatile representative powered-lift aircraft for assessment of navigation and control systems requirements for safe (precise control with low pilot workload) terminal area operations foreseen for this class of aircraft.

Program Targets

- Documentation by December 1974 of augmentor-wing proof-of-concept flights to be completed by May 1974.
- STOL operational assessment by U.S. and Canadian test pilots to be completed by April 1974.
- Development by February 1975 of definitive criteria for control of flight path and airspeed, and for roll and yaw power for powered-lift transports through flight confirmation and refinement of results of analytical studies and piloted simulator experiments.
- Development by February 1975 of flight director laws and integrated controls for transition management through flight evaluation of a flight director concept system developed by analysis and simulation.
- Confirm and extend by 1977, certification criteria for powered-lift aircraft developed through piloted simulation.
- Initiate by November 1974, main body of STOL operating systems experiments (supported under separate program).

Program Approach (Abbreviated Version)

A C-8A aircraft was modified in FY 71 and 72 to incorporate a jet augmentor wing and appropriate jet engines in a joint U.S./NASA - Canadian/ Department of Industry, Trade, and Commerce program. Following contractor check-out flights, the aircraft was delivered in August 1972 to the Ames Research Center where airworthiness and proof-of-concept flights were initiated. During this phase of testing the vehicle was further modified to include a powered elevator and the STOLAND avionics systems to permit handling qualities studies at lower speeds and more realistic long-term flight experiments on STOL operating systems. Parallel studies were undertaken under contract using a variable-stability Navion aircraft to aid in planning the C-8 flight research program. The C-8 handling-qualities experiments will begin in mid 1974 following completion of the proof-of-concept tests and of pilot assessment of the STOL operational characteristics of the aircraft. The main part of the handling-qualities criteria studies will be completed by February 1975. The STOL operating systems experiments will begin in November 1974 utilizing the C-8 augmentor-wing aircraft in a program supported under a separate project. During the course of the latter experiments, the C-8 research aircraft will be used to evaluate flight director laws and certification criteria for powered-lift flight.

Additional details are available in the March 23, 1973 Project Plan entitled "C-8 Augmentor Wing Research Aircraft and Flight Experiment."

Need and Relevancy

OAST has a responsibility to develop short-haul transport technology for high density civil transportation. The C-8 augmentor-wing research vehicle is the first jet powered-lift STOL aircraft to operate. It will therefore enable early examination of low-speed flight and operational characteristics representative of future STOL/RTOL transports, which (with rotorcraft and jet VTOL aircraft) are expected to provide the U.S. with more efficient high-density short-haul systems. Information obtained from STOL handling qualities tests with the aircraft will aid in verifying the results of ongoing and planned ground-based simulator studies, and in providing the criteria to establish civil certification requirements for such aircraft. The vehicle, being equipped with the STOLAND avionics system, will also provide a unique facility for scheduled general STOL transport operating-systems experiments, to be carried out jointly with DOT in a separate program.

QUIET, CLEAN, SHORT-HAUL EXPERIMENTAL ENGINE (QCSEE)

(738-13) Ongoing

Program Objective

Design, build and test experimental engines to consolidate and demonstrate the technology needed for very quiet, clean and efficient propulsion systems for economically viable and environmentally acceptable powered lift short-haul air-craft. Program goals translate as follows:

- 95 EPNdB noise footprint area less than 0.5 sq. mi. (~10% of DC-10), or 500 ft. sideline = 95 EPNdB.
- Emission levels of Experimental Clean Combustor.
- Thrust to weight ratio 6 or better.
- High bypass ratio engine technology for under-the-wing and over-the-wing systems: composite, variable pitch, thrust reversing, low pressure ratio fans with gear reduction drive for low tip speed.

Program Targets

The program objectives will be met through the following steps:

- Source selection and contract award in December, 1973.
- Design layout review - June, 1974.
- Critical Design Review - January, 1975.
- Delivery of first engine to LeRC for in-house testing in an under-the-wing configuration in August, 1977.
- Delivery of second engine to LeRC for in-house testing in an over-the-wing configuration in December, 1977.

Program Approach

The approach is a competitive procurement, single-contractor experimental engine program managed by the Lewis Research Center. System definition/optimization studies of powered lift propulsion concepts in FY 1973 formed the hardware program basis. Two full scale engines, one for under-the-wing installation, the second for over-the-wing will be designed, fabricated, assembled, tested, and delivered to Lewis. Inhouse acoustic and aerodynamic performance testing in wing/flap system installations will be conducted to verify system characteristics and achievement of program goals.

OBJECTIVE DOCUMENTATION

Title: Quiet Short-Haul Research Aircraft (QSRA)

Type of Specific Objective

X System and Experimental Program

Organizational Element Responsibility

Transport Experimental Programs Office - William Gardner/Jack Levine

Statement of Specific Objective and Targets

Objective: To obtain, by means of a low-cost experimental aircraft, quiet propulsive-lift flight research data on an advanced propulsive-lift configuration at lift coefficients greater than 4.5, 90 EPNdB footprint areas smaller than one square mile, and roll control power greater than one radian per second^2. Specific targets are:

- Provide by the end of FY 1974 a Project Plan and Risk Assessment which will include the objectives, technical approach, schedules and cost for the effort and the risk assessment in achieving the same.
- Determine by the end of FY 1974 the airframe and engine design requirements, schedule and cost to modify an existing airplane for use as a low-cost quiet, high performance propulsive-lift research aircraft.
- Modify the design, fabricate and assemble by the end of FY 1976 an existing aircraft with an advanced propulsive-lift system and perform ground checkout and limited flight tests of the assembled aircraft by the third quarter of FY 1977.
- Define by the end of FY 1976 and conduct beginning in the third quarter of FY 1977 appropriate multi-disci-

pline propulsive-lift flight experiments in areas of general configuration, handling qualities, noise, flight dynamics, flight control systems, information displays, propulsion system, and operating environment.

- Generate and verify by FY 1978 the integrated total vehicle and operating systems technology base from which design requirements and certification criteria can be established for practical and efficient quiet propulsive-lift civil and military short-haul transports.

Need and Relevancy

Future powered lift short-haul aircraft need quiet, clean, efficient and economical propulsion systems whose technology is not yet available. Demonstrations of component and system interactions in credible, full-scale engines and propulsion installations are needed to establish the data base to stimulate industry development with acceptable risk, and to help government establish environmental and operational requirements.

Approach

The project will include modification of an existing aircraft into an advanced quiet propulsive-lift configuration with modified existing engines to power the aircraft and the use of the aircraft in a flight research program to achieve the previously stated objective and targets.

Two parallel preliminary design study contracts were awarded on January 3, 1974 to the Lockheed Aircraft Corporation and the Boeing Company for a nine and one-half month period to determine the most effective configuration of the quiet propulsive-lift research aircraft. Each contractor will conduct preliminary design of (1) a C-8A Buffalo aircraft configured with an advanced quieted augmented jet flap (AJF) propulsive-lift system, and (2) a contractor-selected aircraft and quiet propulsive-lift concept. In support of these studies, three separate engine study contracts were awarded on January 31, 1974 to General Electric, Allison, and AVCO Lycoming for a two-month period. The engine contractors will define their engine concepts for the AJF aircraft and for the configuration alternatives being considered by the airframe study contractors.

Approximately mid-way in the design studies it is planned that a single design concept for the research aircraft will be selected by NASA. The selection will be based on results of the contractor efforts as well as on our own in-house studies and considerations will be given to the technical, schedule, and cost risks; the estimated project cost; aircraft research capability; industry interest in the approach; and other related factors. After concept selection the two design studies will complete preliminary design for the aircraft and provide detailed budgetary and schedule estimates for detail design, airframe modification, engine integration, and contractor tests. Results of these studies will be utilized as a basis for issuing an RFP to industry for the engines and for the aircraft. The engine RFP is planned for release in mid-1974 and the aircraft RFP in late 1974. Flight research will be initiated early in 1977.

The flight research program will be developed in a series of steps including the refinement of the established flight research objectives into more detailed and specific objectives, the development of detailed experiments to achieve these objectives, the preparation of a flight experiments program plan that orders and integrates the experiments, and finally, the flight research program itself. The experiments program will be developed in cooperation with other Government agencies and interested industry groups and carried out by NASA as an in-house effort.

The Ames QSRA Project Office is responsible for overall management of the aircraft modification with support by Lewis Research Center to provide modified engines for the aircraft. The QSRA Project Office is also responsible for management of the flight research program with participation by the other OAST Centers.

Major milestones of the QSRA Project are:

Contract award for aircraft preliminary design studies	January 3, 1974
Contract award for engine support studies	January 31, 1974
Select aircraft design concept	4th Qtr. FY 1974
Contract award for engines for modified research airplane	3rd Qtr. FY 1975
Contract award for design, fabrication of hardware and modifications for research airplane	4th Qtr. FY 1975
Initiate NASA quiet propulsive-lift flight research program	3rd Qtr. FY 1977

Initial quiet propulsive-lift flight research results available	4th Qtr. FY 1977
Technology data base available for use in establishing design criteria and development of civil commercial aircraft	FY 1978

Need and Relevancy

The flight research program is necessary in order to reduce the technical risk associated with the development by industry of both civil and military propulsive-lift transports and to provide a comprehensive technical foundation on which Government regulation agencies can establish realistic criteria for certification of commercial subsonic propulsive-lift transport aircraft and for enroute and terminal area operations. A quiet propulsive-lift research airplane must be designed, built and flown in a research program in order to provide verification and demonstration of the technical base for the future design, development, fabrication and operation of reliable, quiet and economic fan-jet propulsive-lift transports. Powered lift technology is a key to community noise reduction, airport congestion relief, and improvement of civil transport and military tactical airlift.

OBJECTIVE DOCUMENTATION

Title: AMST Prototype Aircraft (769-48)

Type of Specific Objective

_X_ System and Experimental Program

Organizational Element Responsibility

Transport Experimental Programs Office - William Gardner/Jack Levine

Statement of Specific Objective and Targets

Objective: To obtain, through participation in the Air Force AMST prototype program, propulsive-lift flight research data on straight-wing externally blown flap configuration at lift coefficients up to about 3.5, 90 EPNdB footprint areas greater than 11 square miles, and roll control power about ½ radian per second[2]. Specific targets are:

- Obtain by FY 1976 flight verification of the detailed performance predicted by NASA ground based research data for USB and EBF propulsive-lift aircraft.
- Define by the end of FY 1974 and conduct on a non-interference basis with the Air Force during FY 1976 to the maximum extent possible multi-discipline flight experiments in areas of general configuration, handling qualities, flight dynamics, noise, flight control systems, information displays, propulsion system, and operating environment.
- NASA completes by FY 1978 documentation of the flight characteristics and evaluation of handling qualities and operational techniques as related to civil short-haul operations.

Approach

NASA's direct involvement in the AMST program includes support of development of the aircraft and participation, through membership of the AMST Joint Test Team, in defining and conducting part of the AMST flight test program. Support of development of the aircraft includes scale-model tests in various wind tunnels to fill voids in available wind tunnel capabilities on the part of the Air Force contractors. Further developmental support is provided through use of the unique ARC Flight Simulator for Advanced Aircraft for assessing adequacy of stability and control levels inherent in the AMST designs, operational procedures and emergency conditions that may influence aircraft configuration and/or control systems characteristics.

The flight program will be conducted in two stages. In the first stage, NASA will accomplish cooperatively with the Air Force such technology-oriented flight research as can be undertaken without interference with the primary Air Force objectives. Recognizing the Air Force objective of the evaluation of these prototypes for tactical and logistic military applications, it is expected that during the Air Force-led flight program, the time devoted to the acquisition of data of interest both to the Air Force and NASA (i.e. basic aerodynamic performance, handling qualities and operational techniques) will be limited. In the second stage, following completion of the one-year prototype evaluation currently scheduled by the Air Force, NASA will assume the primary role and will conduct additional flight research. This second stage of the program will complete the documentation of flight characteristics and evaluation of handling qualities and operational techniques as related to civil short-haul operations. Modifications to the aircraft will be made depending upon a weighing of feasibility and cost, and benefits to the QPLT Program. It is anticipated that installation of STOLAND in one of the AMST aircraft would best facilitate the study of advanced avionics applied to short-haul operations in the terminal area. In addition to studying integration of advanced avionics with pilot display and flight control systems, STOLAND would aid in the evaluation of techniques for defining noise abatement flight patterns in the terminal area. Additional modifications may be made to the aircraft to reduce noise generated by aero-propulsion systems to permit development of criteria for noise certification.

Major milestones of the AMST Prototype Aircraft Program applicable to NASA are:

Initiate Air Force-led flight evaluation of the AMST aircraft	1st Qtr. FY 1976
Initial propulsive-lift flight research results available for EBF and USB configurations	Mid FY 1976
Initiate NASA-led flight research using the AMST aircraft	Mid FY 1977

Need and Relevancy

In considering the requirements for technology and operational data to support development of civil and military transports with the advantages of improved approach, landing, takeoff, climbout, and airport area low-speed maneuvering capabilities, the U.S. Air Force and NASA have agreed that the national needs can best be served through cooperation activity which assures a close working relationship between the Air Force and NASA in the Air Force Advanced Medium STOL prototype (AMST) program and the NASA Quiet Propulsive-Lift Technology programs.

The Air Force/NASA Memorandum of Understanding on the coordination of the Air Force and NASA propulsive-lift programs provides both for NASA participation in the Air Force flight testing of the AMST prototypes and for subsequent use of these aircraft in a NASA-led flight test program. These aircraft can be used to accomplish a part of the objectives of the flight test program planned for NASA's quiet propulsive-lift research airplane to the extent that their performance capabilities permit.

STOL OPERATING SYSTEMS EXPERIMENTS
(768-83) **Ongoing**

Program Objective

Establish a technology base upon which operational STOL short-haul systems can be based with confidence in the 1978-2000 time period.

Regarding NASA STOL technology programs, the draft Federal Plan for Short-Haul Air Transportation Improvement states that "The data from these programs are considered critical to this plan, for this data provides the basis for assessing which short-haul options are the most promising from an operational and technology point of view."

Program Targets

In this joint DOT/NASA program, operating systems technology, operating procedures, and guidance, navigation, and control concepts for high-density terminal area operation will be demonstrated in the following steps:

- Integrated digital avionics research systems (STOLAND) available - July 1973.
- Synthesize flight paths for STOL independent of CTOL operations - September 1974.
- Initiate flight experiments to provide systems performance data
  - DHC-6 June 1974
  - Augmentor Wing C-8 - December 1974.
- Initiation of Microwave Landing System (MLS) validation flight experiments - April 1976.

Benefits which will be demonstrated include:

- Noise - 90 EPNdB footprint within airport boundary.
- Weather - Low visibility automatic landing capability.
- Guidance Accuracy - Maximum touchdown dispersions of ± 15 ft. laterally and ± 100 ft. longitudinally.
- Pilot Workload - Reduced 30% through automation and displays.

Program Approach

This joint DOT/NASA program is being conducted primarily at Ames Research Center, with supporting simulation studies being conducted at Langley Research Center and FAA's NAFEC.

An integrated digital avionics research system (STOLAND) has been provided by Ames Research Center. One simulator STOLAND system and two flight systems have been fabricated. The first flight system has successfully completed flight acceptance tests in the ARC CV-340 aircraft and is currently being installed in a DHC-6 Twin Otter. Flight experiments with this aircraft will begin in June 1974. The second flight system is being installed in the modified C-8A augmentor wing STOL research aircraft and flight acceptance tests will be performed in November 1973. Flight experiments with this aircraft will commence in December 1974.

Introduction of the Microwave Landing System (MLS), now under development by the FAA, will provide better terminal area landing guidance than is presently available. The MLS will by used by CTOL, STOL and VTOL aircraft. Consequently, one task to be accomplished in this program is to support the FAA in development of the MLS to ensure its suitability for STOL applications. Analysis, field investigations, computer simulations and flight experiments will be conducted to define realistic criteria for MLS proof-of-concept evaluation and prototype validations. The field investigations will include ground and flight tests with the programmable STOLAND avionic system. These investigations will emphasize MLS performance for terminal area navigation and approach and landing guidance for low visibility automatic operations. Flight validation of the K model prototype system will be completed in 1977.

In addition to the MLS validation, operating systems experiments will be conducted to provide information to aid in the choice of STOL terminal area guidance, navigation and control system concepts and to define operational procedures. Steep ascents and descents, tight turns and slow speed approaches and landings will be studied using analysis, simulation and flight test. The simulation and flight test experiments will be conducted using the STOLAND avionics system, the DHC-6 Twin Otter and the C-8A augmentor wing research aircraft. The navigation and landing aids to be used in the experiments are VOR, DME, TACAN and MODILS (Modular Instrument Landing System).

Improved navigation and guidance will be investigated using an innovative inertial guidance and navigation concept making full use of digital computer technology and redundancy management. This strapdown inertial reference unit (SIRU), now in the design phase, will be delivered to

ARC in September 1974 for flight acceptance tests in the CV-340. Flight experiments using a STOL vehicle equipped with both STOLAND and SIRU will begin in November 1975.

Additional details will be included in the Program Plan to be available in early 1974.

Need and Relevancy

The Joint DOT/NASA Civil Aviation Research and Development Policy Study report identified the two most important problems plaguing civil aviation as noise and congestion. Development of a National Short-Haul Air Transportation System utilizing the capabilities of STOL aircraft has the potential of reducing the projected terminal area congestion and noise impact.

The ability of STOL aircraft to operate from runways 3000 to 9000 feet shorter than those required for CTOL aircraft and containment of the 90 EPNdB footprint within the airport boundary will allow modification or acquisition of STOL landing facilities with reduced real estate costs. Advanced navigation, guidance, and control systems will provide zero visibility landing capability and maximum touchdown dispersions of ± 15 ft. laterally and ± 100 ft. longitudinally. This will allow STOL aircraft to interface with the ATC system with minimal interference and will permit STOL vehicle operations independent of CTOL operations at existing airports. Reducing the pilot workload by 30% will increase the safety of operations.

New operating systems criteria and procedures must be established. Thus, NASA and DOT, in attempting to solve some of the potential problems associated with STOL navigation, guidance, and air trafic control, have joined forces in conducting a STOL Operating Experiments Program which is discussed in "Final Report of the Flight Experiments Committee of the Joint DOT/NASA Operating Experiments Steering Group," dated July 21, 1972.

4. NASA
ROTORCRAFT/VTOL NOISE TECHNOLOGY PROGRAMS

OBJECTIVE DOCUMENTATION

Title: Advanced Rotorcraft Aerodynamic Technology

Type of Specific Objective

___ Discipline ___ Study ___ System and Experimental Program

Organizational Element Responsibility

Aerodynamics & Vehicle Systems Division - John M. Klineberg

Statement of Specific Objective and Targets

Objectives: to determine and improve the performance, dynamic loads, noise, control, stability, vibration, and handling qualities characteristics of helicopter rotors and rotorcraft configurations in order to permit the development of rotorcraft having substantially greater mission and cost effectiveness than current (1973) operational vehicles in military and civil usage. Specific targets are:

- Rotor Tip Vortices - By FY 1975, verify through full-scale experimental evaluations the projected ability of both passive and active devices, such as the ogee tip shape and mass injection concepts, to reduce blade-vortex impulsive noise about 5 EPNdB compared to conventional square tip blades for rotors of equivalent thrust level.

- Variable-Geometry Rotor - Evaluate the performance and noise characteristics of one of the current RSRA system candidates, the variable-geometry rotor concept, analytically in FY 1975 and experimentally in full-scale static tests in FY 1975-76.

- Controls and Displays for Improved Handling Qualities - Evaluate in flight the handling qualities improvements during curved decelerating approaches achievable with a 3-axis vector velocity command system by FY 1975, and a non-linear control concept by FY 1976.

- Civil Helicopter Technology Assessment - Apply in FY 1975, 1973 state-of-the-art technology on a large transport helicopter (CH-53) to provide passenger compartment acoustic/ and motion environment and assess suitability for feeder line aircraft use, and to provide civil helicopter noise certification and community acceptance criteria.

- Advanced Rotorcraft Design Studies - Define in FY 1975, to the extent possible in modest design studies incorporating estimated technology advancements, the broad design and operational characteristics of large advanced compound helicopter and tilt rotor transports which could realistically be operational by 1985.

- Controllable-Twist Rotor - Verify at full-scale in FY 1975 the ability of a controllable-twist rotor concept to reduce cyclic vibration 10 percent and improve performance 2 percent, compared to 1973 operational rotor types.

- Flight Controls and Handling Qualities for Unique Military Helicopters - Through evaluating a hierarchy of helicopter control systems by 1976, determine the minimum augmentation requirements for specific military low-level missions, and develop methods of implementation to minimize the number and complexity of hardware components. Using moving base simulation, establish by 1975 the effect of gross weight up to 250,000 pounds on handling qualities and flight-control requirements for crane helicopters.

- Design Prediction Methods - Validate existing design predictive methods and modify them where deficiencies exist to provide the required improved understanding of interrelated basic factors contributing to rotorcraft performance, noise, dynamics, and control. The subjects to be examined include: (1) main rotor/fuselage, tail rotor flow interferences and effects by FY 1975, (2) unsteady flow conditions on rotor blades and in the rotor wake by FY 1976, and (3) rotor blade and control system dynamics including feedback by FY 1977.

- Tilt-Rotor Control Systems - Develop and demonstrate by 1978 the technology for advanced control systems suitable for commerical and military operational tilt rotor vehicles.

Approach

The NASA rotorcraft aerodynamic programs are conducted at the Ames and Langley Research Centers--in almost all cases jointly with the Army Air Mobility R&D Laboratory located at each Center. Effort at Ames emphasizes large-scale rotor model tests in the 40- x 80-foot tunnel, ground-based flight simulation studies, and analytical and design studies conducted primarily under contract. Langley in-house studies utilize such facilities as the V/STOL and full-scale tunnels for small-scale rotor model studies, the whirl tower for large- or full-scale hover performance and noise evaluations, and available rotorcraft for flight-dynamics investigations; contracted analytical and experimental studies are also supported. The specific approaches for accomplishing each of the identified targets follow:

- Rotor Tip Vortices - In the program oriented toward reduction of rotor tip vortex strength (and therefore reduction of vibration and noise) rotor tip geometric variations and mass injection will be studied. In one phase, Langley will evaluate the characteristics of full-scale ogee-tip blades on the whirl tower and in flight on the UH-1H helicopter in FY 1975, and Ames will carry out coordinated tests of the UH-1H blades in the 40- x 80-ft. tunnel. Langley will conduct flight tests to evaluate the mass-injection concept in FY 1975-76.

- Variable-Geometry Rotor - In Langley studies of the variable-geometry rotor (VGR), also designed for tip vortex strength alleviation, computer programs will be improved for the calculation of VGR performance and dynamics by FY 1975; following complete performance evaluations of a VGR scale model rotor through wind-tunnel tests in FY 1974, performance and noise tests will be made of full-scale models in FY 1975-76 on the whirl tower.

- Controls & Displays for Improved Handling Qualities - The CH-46 in-flight simulator helicopter will be utilized in FY 1975 to develop improved design and certification criteria for rotorcraft--and other VTOL aircraft--primarily in the areas of handling qualities and overall low-speed flight characteristics, such as during decelerating curved approaches. Advanced flight control systems including a 3-axis vector velocity command concept will be examined by early FY 1975 and a non-linear control concept by early FY 1976. Preparations will be completed for phasing in a CH-47 in-flight simulator (made available through the Army) having an improved research capability. The SH-3A helicopter will be used to fly pilot-controlled, simulated IFR VTOL approaches while varying the electro-optical pilot display parameters (resolution field of view, contrast, magnification factor, etc.) for reduced pilot workload and improved safety.

- Civil Helicopter Technology Assessment - The ride quality improvements achievable from current state-of-the-art design of a quieted vibration-isolated cabin in a CH-53 helicopter will be demonstrated at Langely in FY 1975. Design studies will be continued in FY 1975-77 to define and assess other advanced technology applications for improving performance, safety, economy and community acceptance of civil helicopter transports; flight evaluations of the more promising applications will be conducted in FY 1976-80.

- Advanced Rotorcraft Design Studies - Ames contracted design studies will be completed in FY 1975 to define representative tilt-rotor and advanced helicopter commericial aircraft design models for future short-haul air transportation. (The studies will enable a comparison with the characteristics of other STOL and jet VTOL concepts provided in other similar contracted studies.) Information on these design models, derived from analysis, wind tunnel tests, and simulation will be used to define their operating characteristics--e.g., noise, fuel utilization, flight path, pilot workload, and passenger acceptance--during approach and landing.

- Controllable-Twist Rotor - Ames, in FY 1975, will evaluate the dynamics and performance of a large-scale controllable-twist rotor on a new rotor test rig (RTR) to be developed for the 40- x 80-ft. tunnel. The RTR represents a major improved test capability for Ames, and will be used for a number of large-scale rotor investigations in future years.

- Flight Controls and Handling Qualities for Unique Military Helicopters - Simulation studies will be conducted at Ames of a number of low-level helicopter missions of interest to the Army. A hierarchy of control systems will be investigated during FY 1975 to establish the minimum augmentation requirements and to develop methods of implementation. Emphasis will be given to minimizing the number and complexity of the hardware components, minimizing the effects of upsets and disturbances, and on developing techniques for decoupling controls. By 1975, simulation investigations will be completed to determine the effect of gross weight up to 250,000 pounds on the handling qualities and flight control requirements for crane helicopters up to the very heavy lift class. Simulation results will be validated through use of flight results on a CH-54 helicopter obtained at Langley during FY 1974.

- Design Prediction Methods - Langley will conduct analytical and experimental studies to identify factors contributing to the aerodynamic, dynamics and noise characteristics of rotors. University grants and contracted studies will be continued through FY 1979 to define wake geometry and analytical procedures which include wake characteristics in predicting airloads, structural response, rotor control feedback, performance and noise. Langley in-house experimental studies will be made in FY 1975-77 to better define unsteady local-flow and aeroelastic parameters and rotor system dynamics. Tests will continue in FY 1975 with a highly instrumented generalized research helicopter model in the V/STOL tunnel to obtain a better quantitative understanding of main rotor/fuselage/tail rotor interference flows and effects. The effectiveness of a helicopter fan-in-fin in lieu of a tail rotor will be evaluated in the full-scale tunnel by FY 1976. A sophisticated rotor noise prediction technique will also be computerized in FY 1976. Ames will refine math modeling of tilt rotor dynamics through FY 1975; will continue contracted generalized studies of tilt rotor gust response problems and control system suppression technique through FY 1976; and will develop a method for computing tilt rotor/wing/empenage aerodynamic interference in FY 1975-76.

- Tilt Rotor Control Systems - A simulator model of a commercial tilt-rotor transport will be obtained by 1976 for use in simulation studies to define handling qualities and control system design criteria. Pertinent information will be obtained from coordinated simulation and flight studies supported under the XV-15 Tilt-Rotor Research Aircraft Program (RTOP 744-28-01).

Need and Relevancy

Rotorcraft have attained wide usage by the military (35 percent of the DOD aircraft inventory are helicopters and 85 percent of the Army inventory) for application primarily in assault, medical evacuation, aircrew rescue, aircraft retrieval and ground support missions. There is likewise a growing use of helicopters in the civil sector for industrial, ambulance and police, and short-haul transportation applications. Despite this wide rotorcraft usage, their full potential is far from realized in both military and civil sectors due to technology limitations resulting in poor cruise efficiency, inadequate speed and range capability, poor dynamics and high vibration, bothersome noise, and inadequate all-weather flight capability. These limitations seriously impact mission capability, initial and operating (including maintenance) cost, and passenger and community acceptance. The programs of this objective are aimed at effective alleviation of the technology limitations to permit the realization of rotorcraft having greater mission and cost effectiveness for both military and civil needs. An indication of the relevancy of the programs to military needs is the fact that about 90 percent of the programs are supported equally in funding and manpower by NASA and the Army.

OBJECTIVE DOCUMENTATION

Title: Advanced VTOL Aircraft Aerodynamic Technology

Type of Specific Objective

_XX_ Discipline ____ Study ____ System and Experimental Program

Organizational Element Responsibility

Aerodynamics & Vehicle Systems Division - John M. Klineberg

Statement of Specific Objective and Targets

Objective: To provide the technology required to enable the development of viable military and civil aircraft having effective VTOL capability together with speed, range, operating cost, and mission/operational capabilities approaching those of 1973 operational medium range military and civil CTOL aircraft. This requires the development of a thorough knowledge and understanding of the aerodynamic performance, noise, control and stability characteristics, and piloting qualities peculiar to VTOL system concepts. Specific targets are:

- Ejector Wing VTOL Aerodynamics - In FY 1975, evaluate the VTOL aerodynamic performance, stability, and control of XFV-12A ejector wing configuration. Examine by FY 1976 the performance of advanced high pressure hypermixing VTOL ejector-concepts in forward flight transition engines.

Obtain by FY 1976 a preliminary evaluation of the performance of VTOL ejectors located chordwise at the root of a low aspect ratio combat aircraft type wing.

- Lift-Fan VTOL Aerodynamics - Verify in FY 1975 through large and small-scale tunnel tests that a lift-fan VTOL transport can be configured to achieve satisfactory performance, control and stability characteristics in terminal area operation.

- Lift/Cruise Thrust Vectoring - Demonstrate by FY 1975 through large-scale static tests the technology for rapid response (± 20% thrust modulation and ± 20° thrust deflection in 0.2 sec.) lift/cruise propulsion system thrust vectoring/modulation systems whose thrust vector can be varied in a practical design from 0° (cruise thrust mode), to 90° (hover lift mode) with no more than 5% thrust loss, and to 130° for thrust reversal/braking.

- Lift/Cruise VTOL Aerodynamics - Demonstrate by FY 1976, technology for applying basic fluid mechanic phenomena to improve transition-flight interference effects on performance, stability and control of selected military VTOL combat type configurations through wind tunnel evaluations of small-scale models.

- SCS VTOL Aircraft Handling Qualities - Establish by FY 1976 through simulator investigations the envelope of acceptable approach aspects (relative headings of aircraft, ship, and wind) for satisfactory handling qualities of VTOL aircraft on Sea Control Ships under various sea states and weather conditions.

- Land-Based VTOL Aircraft Handling Qualities - Devise and demonstrate by FY 1977 an integrated control system for all flight phases of high-performance VTOL transport type aircraft. Verify through X-14 flight tests and related simulation studies, design criteria for vehicle lateral control power in hovering by FY 1975.

- VTOL Flow Interactions - Provide predictive methods adequate for design needs by FY 1978 of complex flows and their interactions (including noise effects) typically associated with VTOL aircraft having concentrated propulsion/lift system inlet and exhaust flows. As one specific example, a satisfactory analytic method for predicting vehicle induced lift accruing from lift engine propulsion installations in wing mounted pods will be sought in FY 1976.

Approach

The high performance VTOL aerodynamic programs are conducted at Ames and Langley. At Ames, the primary emphasis is on large-scale aerodynamic performance and acoustic studies, and on handling quality investigations. Langley concentrates on small-scale model investigations of aerodynamic performance, stability and control. NASA funding for the joint USN/USAF, NASA, FAA X-22 handling qualities program has been directly from Headquarters with technical monitoring by Langley. The approach toward accomplishing each identified target and the major milestones is as follows:

- Ejector-Wing VTOL Aerodynamics - Langley in FY 1975 will evaluate the VTOL aerodynamic performance, stability and control of small-scale wind-tunnel and free-flight models of XFV-12A VTOL aircraft configurations, and Ames will test the actual aircraft in the 40- x 80-ft. tunnel if provided by the Navy. Ames in FY 1975 will continue exploratory investigation of hypermixing VTOL ejectors, which will be extended in FY 1976 to advanced ejectors having pressure ratios perhaps as high as 2 to 3. Ames in FY 1975 will investigate the feasibility of VTOL ejectors located axially in the chordwise direction near the root of low aspect ratio military type aircraft configurations of VTOL performance in FY 1976.

- Lift-Fan VTOL Aerodynamics - The characteristics of a current technology lift-fan civil transport model and of a military multi-mission lift/cruise fan configuration will be determined in large-scale powered model tests on the Ames static test stand and in the 40- x 80-ft. tunnel in FY 1975. Langley in FY 1975 will complete small-scale model investigations of the performance, stability, and control of an intercenter VTOL transport model incorporating a different wing-pod-mounted lift-fan configuration, and of McDonnel Douglas VTOL transport design. On the basis of these results, Ames in FY 1976 will initiate the design of a more advanced VTOL transport type model for the 40- x 80- ft. tunnel, having substantially less required thrust/weight than current designs, to develop the integrated aerodynamic and acoustic technology.

- Lift/Cruise Thrust Vectoring - Ames in FY 1975 will complete a first series of small- and large-scale static tests of lift/cruise fan nacelles and thrust vectoring vehicle control systems aimed at developing technology for simple lightweight systems that can meet the stringent requirements for large vectoring angular ranges, fast angular and thrust modulation, high temperatures, and acceptable interactions of the exhaust flow with the aircraft, ground, and airstream.

- Lift/Cruise VTOL Aerodynamics - Langley in FY 1975 will continue wind tunnel evaluations of small-scale VTOL combat type aircraft configurations with wing and lift jet relative positions varied to optimize jet interference effects on performance, stability and control during transition flight.

- SCS VTOL Aircraft Handling Qualities - Ames will continue in FY 1975 and complete in FY 1976 a first series of simulator investigations to establish the envelope of acceptable approach parameters for satisfactory handling qualities of VTOL aircraft under manual control during take-off, approach, and landing on Sea Control Ships under severe weather conditions. Additional investigations will extend into FY 1977.

- Land-Based VTOL Aircraft Handling Qualities - Research at Ames toward demonstrating by FY 1977 an integrated flight control system for high performance VTOL transport type aircraft will include in FY 1975: (1) analytical and simulation studies of such a control system; (2) continued X-14 flight investigations to extend and refine hover control system and handling quality design criteria determined through simulation; (3) completion of simulation math models of advanced V/STOL transports to support transportation systems terminal area efficiency studies and; (4) initiation of a major simulator study on the FSAA to examine in considerable detail how best to detect and handle system failures on representative VTOL aircraft designs during critical conversion flight regimes (this effort will extend into FY 1977). Reporting of the X-22 flight evaluation of VTOL curved decelerating approaches, monitored by Langley, will be completed.

- VTOL Flow Interactions - Ames by FY 1976 will attempt to devise satisfactory theoretical methods to predict induced flows for VTOL podded configurations. Generalized studies will continue through FY 1978 at Langley on VTOL crossflow interferences, and at Ames, on the noise of VTOL exhaust jets as related to turbulent mixing.

Need and Relevancy

Efficient high-density short-haul civil transportation systems for the future have a need for quiet efficient vehicles which can operate over short to modest stage lengths competitively with other forms of transportation from small inexpensive VTOL ports which can be readily located to meet transportation demnds with a minimum impact on the community environment and with an economic advantage to both the traveling public and the communities being served. Likewise, the DOD has a requirement for future carrier-on-board delivery (COD) logistic and surveillance type VTOL aircraft which can be operated from small Sea Control Ships, as well as for VTOL combat aircraft. There is considerable commonality in the vehicle technology requirements for both the civil and military needs. The programs of this objective are oriented to provide the vehicle aerodynamic and flight dynamics technology required to develop viable vehicles for such civil and military needs.

TILT ROTOR RESEARCH AIRCRAFT

(744-28) Ongoing

Program Objective

Demonstrate advanced rotorcraft technology for military and civil VTOL vehicles having twice the cruise speed of the helicopter while retaining its efficient hover capability.

Program Targets

Major targets of this program include the following:

- Initiate detail design - August 1973.
- Critical design review - August 1974.
- Fabricate two tilt rotor aircraft - October 1975.
- Complete ground testing - May 1976.
- Start flight research - June 1976.

- Definitize advanced flight research program - July 1977.

Program Approach

Under a joint agreement signed November 1, 1971, NASA and the Army are sharing the funding and management of this program. A jointly staffed project office is located at the Ames Research Center.

Two contractors participated in a Phase I competitive design and analysis which was the basis for the selection of a Phase II contractor. The Bell Helicopter Company was awarded a contract on July 31, 1973, for the design, fabrication, and flight test of two Tilt Rotor Research Aircraft.

The program will be conducted on an "experimental shop" basis to emphasize cost and time savings as well as controlling the technical aspects to insure the aircraft will best meet the research objectives. Prior to first flight, a comprehensive ground test program will be conducted, including tie-down and full-scale wind tunnel tests.

Ames' flight simulators will be utilized to verify aircraft characteristics and to familiarize Army/NASA operating personnel with normal and emergency procedures. The initial flight tests will be conducted at the contractor's facility to verify flight safety and train Army/NASA flight personnel. NASA facilities will be used for proof-of-concept flight tests and definition of the advanced flight research program.

Need and Relevancy

Helicopters have been widely accepted for both civil and military missions where efficient hover and VTOL capability are required. Their application to a wide range of civil short-haul and military tactical roles has been restricted, however, because of high dynamic blade loads and the loss of propulsion efficiency at higher forward flight speeds. Noise, vibration, high maintenance costs, and poor ride qualities have also added to the limitation of the helicopter.

For the past twenty years, the Army, Air Force, NASA, and industry have been pursuing the establishment of a tilt rotor technology base. Based on in-house studies and analyses by NASA/Army engineers, it was concluded that the tilt-rotor concept showed the greatest promise for a capability to meet the military and civil V/STOL needs anticipated in the future.

ROTOR SYSTEMS RESEARCH AIRCRAFT

(745-79) Ongoing

Program Objective

A unique flight test capability in 1976 for advanced rotor research on a wide variety of promising new rotor concepts.

This program will expedite improved rotorcraft research through the use of a specially designed flight test vehicle. Extensive on-board instrumentation will provide better research data, and repeated use of the test vehicle will enable timely and economical completion of rotor research projects.

Program Targets

Major targets of this program include the following:

- Initiate detail design - December 1973.
- Critical design review - December 1974.
- Fabricate two Rotor Systems Research Aircraft - September 1975.
- Initiate contractor flight test - November 1975.
- Aircraft delivery to Government - December 1976.
- Initiate NASA/Army rotor research program - January 1977.

Program Approach

NASA and the Army are jointly funding and managing this program under an agreement signed November 1, 1971. A joint project office is located at the Langley Research Center where the rotor research program will be conducted. NASA/Army in-house and two contractor pre-design studies were used to establish the feasibility of an advanced flight research vehicle and to define its characteristics, the flight control system, and the research instrumentation systems.

An RFP was issued, proposals were evaluated, and Sikorsky Aircraft was awarded a contract for the design fabrication, and flight test of two Rotor Systems Research Aircraft.

Supporting research and technology efforts will be conducted, as required, to support the design effort and reduce the technical risk of the project. Wind tunnel tests will be conducted and the Flight Simulator at Ames Research Center will be utilized.

The "experimental shop" concept will be used to stress time and cost savings in addition to controlling the technical aspects to insure the aircraft will best meet the research objectives.

After a thorough ground test program, the contractor will conduct airworthiness flight tests, determine the aircraft characteristics and handling qualities, and check out the research instrumentation.

The NASA/Army research program will be started shortly after the aircraft are accepted by the government.

Need and Relevancy

The expanding role of the helicopter in both civil and military applications has generated requirements which exceed the current state-of-the-art of rotary wing technology. To date, flight tests of promising advanced concepts have been conducted by modifying an existing aircraft or by building a new aircraft for each concept. This approach is time consuming, costly, and often gives less that good results.

NASA and the Army have been looking for a way to conduct adequate and timely investigations and demonstrations of advanced concepts in flight without the excessive time, cost, or data limitations of the "one at a time" approach. Both agencies have concluded that a specially designed research aircraft with adequate instrumentation is needed to test advanced rotor concepts and verify rotorcraft supporting technology. The Rotor Systems Research Aircraft is planned to fulfull this need.

ROTOR SYSTEMS FOR RSRA

(766-79) New Start

Program Objective

Select, acquire, and evaluate on the Rotor System Research Aircraft (RSRA)--now being developed jointly by the Army and NASA--three practical advanced rotor-system concepts. Demonstrate through tests of these concepts in the real flight environment the integrated performance, dynamics and acoustics technology improvements achievable, such as increased speed (above 300 knots), with attendant lower vibration levels (by ½), noise (below 95 PNdB at 500 feet), and extended component life (by 100%), leading to community acceptance, improved ride comfort (to feederline aircraft levels), and reduced direct operating costs (by 20%). Particular objectives will depend in large part on the three rotor system concepts selected. Concepts currently considered promising include the:

- Aero-acoustic rotor for reduced external acoustic noise and increased cruise L/D
- Variable-geometry rotor for reduced external acoustic noise and rotor vibration and increased hover efficiency
- Composite structures rotor for reduced rotor system weight
- Variable diameter rotor for increased cruise speed
- Controllable twist rotor for increased cruise speed and L/D, increased hover efficiency and reduced rotor vibration

Program Targets

The program objectives will be approached through the following steps:

- Initial selection of rotor systems by mid FY 1975.
- Begin design and fabrication of first rotor system by late FY 1975, ground tests by mid FY 1977, and flight tests by early FY 1978.

- Begin design and fabrication of second rotor system in mid FY 1976, ground tests by late FY 1977, and flight tests by mid FY 1978.

- Begin design and fabrication of third rotor system by mide FY 1977, ground tests by early FY 1979 and flight tests by late FY 1979.

Because the program involves evaluating advanced rotor concepts on a new flight test facility, strong supporting technology efforts will be conducted during FY 1975-77 to aid in establishing design criteria for the rotor systems and guiding their development to assure a successful program.

Program Approach

The technical approach will encompass four major related elements conducted cooperatively with the U.S. Army:

1. Direct Supportive Research & Technology Activities - This includes (a) evaluation of advanced technology airfoils and components which will likely be incorporated into selected advanced rotor system concepts as described in item 2; (b) scale model dynamic investigations of some of the candidate advanced rotor concepts; and (c) correlation of analytical prediction and flight data obtained as described in item 4.

2. Advanced Rotor System Concept Definition Studies & Selection - Concept definition studies will be made under contract to serve as the basis for the eventual selection of the initial three concepts for investigation on RSRA. The definition study contracts will document information on concept potential, preliminary design data, development support requirements, and cost/schedule relationships necessary for subsequent preparation of proposal requests and contract award to procure the rotor systems.

3. Advanced Rotor Systems Design & Procurement for RSRA - This includes the design, fabrication and ground test of three advanced research rotor systems in a manner to provide flight hardware consistent with the RSRA flight schedule. Priorities and sequencing of the hardware development will be based in part on concept potential, on extent of development and full-scale ground test requirements, and on timeliness.

4. Flight Evaluations Utilizing RSRA - Upon delivery of the RSRA, documentation flight tests will be made to evaluate system capabilities and provide baseline data for correlation with future test results. Thereupon, extensive flight investigations will be made of each of the three research rotor systems provided by this systems technology program. During the course of evaluating the three rotor systems per se as they become available, there will be additional flight evaluations utilizing the unique versatility and capability of the RSRA to study important broad helicopter problem areas such as: (a) control system technology including feed-back systems for gust alleviation and ride comfort, (b) rotor/airframe structural dynamic response, and (c) compound helicopter maneuver characteristics.

Need and Relevancy

The NASA and Army are jointly developing two RSRA vehicles at a cost of $33M to provide an efficient, expanded and economic capability (1) to evaluate potentially superior, advanced technology rotor system concepts in flight; (2) to investigate rotorcraft systems and characteristics over a much greater envelope of flight conditions than achievable with currently available laboratory facilities or flight vehicles; and (3) to provide an extensive flight data base to validate many complex rotorcraft design prediction methods. Development of the RSRA vehicles is being agressively pursued to provide the expanded test capability for evaluating a number of rotor concepts at a substantial cost savings compared to the current approach of validating each advanced concept on separate "one shot" test vehicles. The RSRA project is completed upon government acceptance of the aircraft, however, and this research program is required for utilization of the valuable national test facilities to achieve the return on their investment in a cooperative effort with the U.S. Army.

The first RSRA vehicle is scheduled to be delivered to the Langley Research Center by the mid FY 1977 with its baseline rotor system, and to be ready for initial evaluation of an advanced research rotor system by late FY 1977. On the basis of R&T base technology programs to date, several rotor system concepts appear to warrant the thorough flight evaluation which RSRA will permit. However, none of the rotor systems exist in flight hardware suitable for direct use on RSRA. Although the time requirements for design, fabrication, ground test, and integration of a complete rotor system on RSRA will vary with different concepts, a minimum of about two years is anticipated. Therefore, it is imperative that concept definition studies and evaluations be initiated early in FY 1975 to select the most appropriate rotor systems for development, to establish a concept priority which will allow the most effective development of flight test hardware, and to begin the design/fabrication of the first research rotor system. The provision and evaluation of the second and third rotor systems of this program are timed for maximum effective utilization of the two RSRA vehicles for all NASA/Army flight investigations requiring the vehicles.

The development of advanced rotor systems and their evaluation of RSRA contribute directly to the NASA National Goals of providing efficient short-haul transport technology and establishing the technology for superiority in military aeronautics. The program will in addition aid greatly in focusing technology efforts carried out under the NASA Rotorcraft Research and Technology Base programs which also support the two National goals mentioned.

OBJECTIVE DOCUMENTATION

Title: SCAR Propulsion Technology

Type of Specific Objective

___ Discipline ___ Study _X_ System and Experimental Program

Organizational Element Responsibility

Advanced Supersonic Technology/Hypersonic Research Office -
W.S. Aiken, Jr.; L. Sternfield

Statement of Specific Objective and Targets

Objective: To establish an expanded supersonic propulsion technology base in parallel with the expansion of other supersonic disciplinary technologies which will permit the reduction of noise in takeoff and landing to levels less than the Douglas DC-10 and Lockheed 1011; reduce fuel consumption rates which can make supersonic cruise aircraft significantly more efficient; and nitric oxide emissions in high altitude cruise that are greatly reduced from levels possible with today's technology. Specific targets are:

- By the end of FY 1975, establish noise reduction potential of suppressors for coannular jets for application to duct-heating turbofan cycle engines.
- By FY 1977, verify the potential of NO_x reductions to 90% less than current engines at supersonic cruise altitudes.
- By FY 1977, verify inlet shock stabilization valve concept operational suitability by YF-12 flight tests.
- By FY 1979, synthesize and apply an integrated propulsion control system to the YF-12.

Approach

NASA's fundamental research on supersonic propulsion system problems is conducted primarily by LeRC, with contributions from ARC in the noise area and FRC in the area of inlet control systems. Primary emphasis is placed on the development of engine components and propulsion

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systems which will provide high levels of propulsive efficiency with reduced levels of noise and pollutant emissions. The secondary emphasis is on the development of integrated control systems which will stabilize inlet shock waves and thus provide for improved propulsion system performance and reliability.

- Noise suppressors developed in the FAA SST Phase II Follow-on program and in-house LeRC programs will be flight tested using the Lewis F-106 and also tested in Ames 40' x 80' wind tunnel. The sources and treatment of coannular jet noise, important for applications to duct-heating turbofan engines, will be studied by Lewis leading to later engine tests. Wind tunnel techniques to be developed by ARC for the prediction of the effects of forward speed on noise characteristics will lead to testing of powered models of supersonic cruise aircraft.

- The LeRC will continue the current in-house/contractor clean combustor program which is aimed at reducing the NO_x emissions at supersonic cruise speeds to levels which are only 90% of those of current subsonic aircraft. Tests of candidate combustors will be tested at flight conditions representative of those of long-range supersonic cruise aircraft and these tests will lead to the development of Low NO_x combustors suitable for use in low-noise engines.

- Inlet shock stabilization valve concepts and digital integrated control techniques will be applied by the Lewis and Flight Research Centers to the YF-12 aircraft. The shock stabilization system will be tested in the Lewis 10' x 10' wind tunnel and subsequent flight tests will be conducted on a YF-12 which has been modified to include the new system.

Major milestones of the SCAR Propulsion Technology program are:

Early FY 1975 - Initiate wind-tunnel tests of inlet shock stabilization valve.

Mid FY 1975 - Initiate studies of augmentor pollution.

Early FY 1976 - Establish noise reduction potential of suppressors for coannular jets.

Need and Relevancy

The SCAR Propulsion research is for direct support of the Supersonic Cruise Aircraft Research program. This work is of primary relevance to the OAST focus on basic research on supersonic cruise aircraft.

The propulsion system is always a key technology area in the development of any advanced aircraft. In the case of supersonic cruise aircraft, additional constraints imposed by the need to reduce terminal area noise (less than new widebody civil aircraft) and terminal area and upper atmosphere pollution (ninety percent less than current engines at high altitude cruise), while retaining cruise efficiency for military aircraft and economic viability for civil aircraft, present a set of interlocking problems which must be addressed through noise suppression programs, clean combustor programs, and the initiation of research on advanced low-noise engines which permit efficient operation at both subsonic and supersonic speeds. In addition, since very precise and complex propulsion controls are required to prevent major interactions of propulsion system components as well as potentially adverse interactions with airframe control systems, research on the dynamics and control of supersonic propulsion systems must be conducted by means of wind tunnel and flight tests.

We expect that the results of this research will provide the background data which will lead to quieter, cleaner, and more efficient propulsion systems for both military and commercial supersonic airplanes.

OBJECTIVE DOCUMENTATION

Title: Supersonic Cruise Aircraft (SCAR) Aerodynamic Performance Technology

Type of Specific Objective

___ Discipline ___ Study _X_ System and Experimental Program

Organizational Element Responsibility

Advanced Supersonic Technology/Hypersonic Research Office -
W.S. Aiken, Jr.; L. Sternfield

Statement of Specific Objective and Targets

Objective: To establish an expanded supersonic aerodynamics technology base in parallel with the expansion of other supersonic disciplinary technologies which will permit improvements in L/D, reductions in sonic boom, and the translation of technical advances into integrated aircraft systems. Specific targets are:

- By FY 1977, validation of low-speed high-lift aerodynamic performance theories.
- By FY 1978, verification of theoretical methods for rapid analysis of critical design loads.
- BY FY 1979, 30% increase in L/D over present state-of-the-art for aerodynamic configurations meeting all propulsion system, structure, and control system restraints.
- By FY 1981, 40% reduction in sonic boom during cruise conditions potentially applicable to far term advanced supersonic transport designs.

Approach

NASA's fundamental research on supersonic aerodynamic performance is conducted primarily by the Langley and Ames Research Centers. Primary emphasis is placed upon evolving supersonic cruise aircraft concepts which have high levels of supersonic performance, on obtaining sufficient low-speed and supersonic wind tunnel data to permit optimization of these concepts, and on the development of improved theoretical methods for use in the design and analysis of both military and commercial supersonic aircraft. The secondary emphasis is on the development of a more complete understanding of the sonic boom phenomena which are so critical to commercial overland supersonic flight.

- Integrated supersonic cruise configuration concepts which show promise of meeting the demanding requirements of future long-range supersonic cruise missions will be developed by LaRC with extensive analyses and wind tunnel tests. Both "near-term" concepts, which depend on only small improvements in the related disciplines of structures, propulsion, and flight controls to become viable supersonic cruise aircraft, and "far-term" concepts which depend on extensive technology advancements in all areas, will be considered. In addition, the ARC will give consideration to unconventional concepts which might show future promise in an advanced technology environment.

- The purpose of the theory development program is to fill the voids apparent in the recent United States SST program. Needs for improved, and more rapid, means for supersonic cruise aerodynamic design and analysis methods; more valid means for predicting critical wing and fuselage design loads; and methods for analytically assessing the low-speed, high-lift aerodynamic performance were indicated during this program. LaRC will conduct contract studies to meet the needs for better supersonic and loads methods while ARC will direct a contract study to fill the need for improved low-speed methods. The goal is to combine the improved methods into a unified design and analysis method which is applicable to most classes of supersonic aircraft.

- It is generally accepted that the future market for commercial supersonic cruise aircraft would be more than doubled if the sonic boom problem could be solved of ameliorated. The SCAR sonic boom technology will be directed towards obtaining a better understanding of sonic boom pehnomena and towards evolving configuration concepts which have low levels of sonic boom disturbance.

Major milestones of the SCAR Aerodynamic Performance research are:

Early FY 1975 - Complete Cornell University study of sonic boom phenomena.

Mid FY 1975 - Extend contracts for improved supersonic loads, and low-speed theory.

Late FY 1975 - Complete transonic tests of arrow-wing propulsion and pressure distribution model.

Need and Relevancy

The SCAR Aerodynamic Performance research is for direct support of the Supersonic Cruise Aircraft Research program. This effort is of primary relevance to the OAST focus on basic research on supersonic cruise aircraft.

Improved aerodynamic performance in all flight regimes is critical in the development of superior military and commercial airplanes. A thirty percent increase in L/D would provide the option for an approximate thirty percent increase in range or payload capability. In the case of supersonic commercial airplanes, the additional constraint of sonic boom and the need for high levels of low-speed aerodynamic efficiency to reduce noise, seriously complicate the aerodynamic design and integration problems. In order to provide the technology for future supersonic cruise aircraft with either military or commercial missions, advanced configuration concepts must be evolved, advanced theoretical procedures for use in predicting and optimizing the aerodynamic performance must be validated, and an extensive data base must be obtained from wind tunnel tests of representative models. The SCAR Aerodynamic Performance research is directed toward these needs.

SHORT-HAUL TRANSPORTATION SYSTEMS ANALYSIS

The objective of this work is to help develop a sound technological base for future decisions relating to the design, development, and operation of short-haul transportation systems. This objective will be achieved through a related group of studies that: examine the relationships between short-haul technology and short-haul economics, markets, and implementation; identify potential viable short-haul airplane concepts and their design and performance criteria for practical short-haul transportation systems including consideration of market, economic, and environmental factors; and, perform sufficient aircraft design to provide a realistic assessment of technical problems and questions regarding their design, development and operations, and their development and operational costs. These data will be used to help define the future direction of productive technical (and system related) activity for short-haul transportation systems. This investigation will be performed in-house and under contract.

Two contracted studies (Lockheed and Douglas) to determine the operational and economic viability of turbofan powered propulsive lift aircraft for short-haul transportation have been completed. Final reports will be distributed in June. The current contracts have been extented to (a) allow Lockheed to optimally design and compare the OTW/IBF propulsive lift and mechanical flap concepts in terms of noise impact and operating economics and (b) allow Douglas to determine the impact on operating economics of the effect of combining terminal area operations with various engine cycles to minimize community noise impact for several propulsive lift and mechanical flap concepts.

ANALYSIS OF FUTURE CIVIL AIR TRANSPORTATION SYSTEMS AND CONCEPTS

The objective of this study is to provide systems analyses of future civil air transportation systems and concepts in order to identify promising aeronautical systems, determine optimum characteristics, and define technology requirements and costs associated with such systems. Studies of general aviation aircraft, CTOL, STOL, and VTOL transports, advanced subsonic/transonic transport aircraft, and advanced supersonic transports will be conducted. Total system studies will be carried out considering all of the interactions between aircraft, airports, airways, community impact, and economics (both within the aviation industry and on a national basis). In addition, studies of a short term nature will be conducted in support of the aeronautical program planning activities of ARC and OAST.

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HIGH TRANSONIC SPEED TRANSPORT (HiTST) SYSTEM STUDY

The objective of this study is to provide detailed configuration definition of a high transonic speed transport concept. The contract system study of FY 1973 identified a promising yawed wing aircraft at the conceptual design level. The study this year will provide needed definition at a more detailed level, providing in-depth analysis in several individual new technology areas, and adding credibility to certain design concepts. Examples of such design studies would include fatigue and flutter characteristics of composite structures, low speed stability and control of yawed wing for emergency maneuvers, and new engine technology applications for reduced noise.

SUBSONIC/TRANSONIC C/RTOL TRANSPORT TECHNOLOGY SYSTEMS AND DESIGN STUDIES

This work covers systems and design integration studies for subsonic C/RTOL long and medium-range passenger and cargo transport aircraft. The objective is three-fold. (1) Make technology advances available for superior subsonic C/RTOL transport aircraft to satisfy anticipated requirements in the 1980's. Anticipated requirements include the need to improve aircraft cruise efficiency not only for better economics but also for energy (fuel) savings; to alleviate terminal-area congestion; and to reduce aircraft noise and emissions without suffering economic penalties. (2) Determine the feasibility of utilizing aircraft fuels other than JP fuel for subsonic cargo and passenger aircraft as a potential partial solution to a projected shortage of petroleum in the 1990's and to identify aircraft-technology requirements peculiar to alternate fuels. (3) Investigate new approaches to providing more economical subsonic transport of liquid and solid cargo in anticipation of the need for a greatly increased air transport of cargo.

SUBSONIC/SONIC CTOL TRANSPORT TECHNOLOGY PROPULSION STUDIES

NASA has initiated an effort to study the application of advanced technology to the improvement of future commercial transport aircraft. The results were resolved in terms of economic factors involving parameters such as aircraft drag, propulsion efficiency, costs, and propulsion system noise and exhause emissions. Detailed analyses has been completed through in-house and contract studies and have been documented in NASA Contractor Reports. Results indicated that the environmental constraints imposed compromises to the the optimum fixed-area turbofan cycle with resulting economic penalties. The studies also indicated areas where advanced technology would decrease the noise and emissions and improve the system economics.

Results of recent studies of unconventional cycles have indicated that to achieve low noise, variable geometry inlets in conjunction with variable-area exhaust nozzles will be needed. Also, the use of high throat Mach number inlets appear to offer significant performance and economic improvement over inlet splitter rings. Several designs, including hybrid variable geometry cowls, expanding and translating centerbody types, and translating ring-type inlets were proposed for further study.

OBJECTIVE DOCUMENTATION

Title: General Aviation Aerodynamic Technology

Type of Specific Objective

XX Discipline ____ Study ____ System and Experimental Program

Organizational Element Responsibility

Aerodynamics & Vehicle Systems Division - Roger L. Winblade

Statement of Specific Objective and Targets

Objective: To develop and demonstrate advanced technology for general aviation use that will permit the design of future U.S. aircraft that are safer, more productive and clearly superior to foreign competition.

The following targets have been established to provide the advanced capabilities and design techniques necessary to achieve the stated objective.

- Flight demonstration in FY 1975 of low speed airfoils with a 30% increase in C_{Lmax} maintaining the same or less cruise drag.
- Application of supercritical aerodynamic technology by all U.S. business jet manufacturers by 1975.
- Flight demonstration by FY 1976 of pilot displays and control systems to improve flight path control and landing performance with special application to
  - pilot training
  - pilots who fly infrequently
  - landing at unfamiliar airfield
  - night landings
  - emergency conditions
- Provide definitive design criteria, test, and evaluation techniques by FY 1976 for aircraft that will not spin unintentionally.
- Establish design criteria for airfoil sections and planforms optimized for low noise propellers by FY 1976.

Pages 150, 151 and 152 [illegible] [illegible]

Approach

Analytical and experimental efforts are directed toward the generation of design data for safer more productive general aviation aircraft. Simulators, wind tunnels and when appropriate, experimental aircraft will be utilized in programs addressing the problems and limitations unique to the general aviation category of aircraft. Improved safety and utility are predominate factors; however, user requirements, manufacturing and cost limitation and certificability are significant factors in development and conduct of the technology programs.

- Both analytical predictions and wind tunnel testing have been used to develop a new low speed airfoil section. The characteristics of the new airfoil show an increase of 30% in C_{Lmax} and a 50% improvement in L/D when compared to airfoils currently in use. Experimental flight verification will be accomplished through the testing of a modified aircraft incorporating new wings designed with this airfoil section. The wing design was completed in FY 1973 with fabrication by a general aviation manufacturer underway in FY 1974. Detailed flight testing in FY 1975 will provide a completed data package including analysis, wind tunnel data, application techniques and flight verification.

- Supercritical aerodynamic theory, while developed in the context of large transports and military aircraft, will be of significant advantage to business jet aircraft. Classification of supercritical data requires implementation of specific agreements under which the necessary access to data can be authorized. Such agreements, providing data, technical consultation and NASA wind tunnel validation of the resulting designs, are in effect with four U.S. business jet manufacturers. Discussions are underway with the remaining two U.S. companies concerning similar arrangements.

- Direct modulation of the L/D ratio has been shown to provide significant improvements in the precision of flight path control and reduction in touchdown dispersion when properly integrated into the pilot's task. The successful completion in FY 1974 of the direct drag control (plate spoilers) effort to demonstrate the feasibility of using spoilers on powered light aircraft is being followed by a similar effort on direct lift control in FY 1975 and FY 1976.

An aircraft modified to incorporate the slot spoiler lift modulation concept will be utilized to obtain definitive data on effectiveness and operational characteristics. Simulation and actual flight tests of an experimental "breadboard" version of a simple head-up display presenting information on angles of attack and sideslip as well as airspeed have shown a beneficial effect on the landing performance of selected pilots with considerable experience in light aircraft. Continuing flight verification of this and an improved prototype version will be performed with pilots of lesser skills and experience to demonstrate the effectiveness of the unit and application in the operational environment.

- The stall/spin problem currently is the largest single factor in general aviation fatal accidents. The program initiated at the Langley Research Center in FY 1973 to define the criteria and design techniques for spin resistant airplanes is intended to alleviate that problem. Exploratory investigations will be conducted at Langley and Ames on both aerodynamic and avionic methods for preventing stalls and spins. Wind tunnels, radio controlled models and full scale aircraft are being used to identify and document the critical aerodynamic characteristics relative to spin entry and recovery. Modernization of the tail damping power factor criteria is a primary aim of this effort, as is the development and demonstration of an economically viable radio controlled model testing technique for preflight verification of spin characteristics. A compact and easily-installed spin recovery system employing monopropellant (hydrogen peroxide) thrusters and a self contained fuel supply system is to be developed and flight tested to demonstrate the suitability of this type of system for basic spin research and possible use by manufacturers in their spin certification tests.

- Both in-house and university grant efforts are being directed toward development of modern design criteria for propellers. Operational and manufacturing compromises have resulted in propellers that currently operate well below the theoretical maximum efficiencies. During FY 1975 and 76, concentration will be on application of advanced aerodynamic theory to optimizing planforms and airfoil sections for maximum noise. Optimized blade shapes will be fabricated from both conventional materials and composites to investigate potential benefits of the newer manufacturing techniques.

Need and Relevancy

The impact of general aviation on the air transportation systems in terms of numbers of operations, flight hours, and people transported has been well documented. The projected large increases in this activity are validated by past history. With 500 million intercity travelers projected to be using general aviation by 1985, it is imperative that a vigorous technology program be directed at improving the safety of these operations.

The general aviation industry in the United States currently exports 20 to 30% of its production. This market has been maintained primarily through the technical superiority of the U.S. manufacturing. Countries in Europe, South America, and Asia, through government support, are rapidly developing their general aviation industries. Projections to the 1985 time period indicate that unless the U.S. industry can generate aircraft that are technologically superior, the emerging foreign competition will not only absorb the export market but will make significant inroads into the domestic market as well.

SPECIFIC OBJECTIVE

Title: Quiet, Clean General Aviation Turbofan

Management Responsibility

David J. Miller/Aeronautical Propulsion Division

Specific Objective

The specific objective of this program is to identify, extend, and demonstrate the technology applicable to small general aviation turbofans to achieve future environmental requirements with economic viability.

Targets

- Perform studies to define an experimental technology demonstration program, January 1976.

• Contract award	February	1976
• Critical design review	June	1976
• Delivery of experimental engine for test	May	1977

Need and Relevancy

The use of small aircraft has the potential to create a more widespread adverse community reaction to jet noise and pollution than do transport aircraft. This is so because minor airports used by small aircraft are apt to be located near suburban residential areas unprotected by commercial/industrial buffer zones. Jet powered general aviation aircraft sales are increasing at a faster rate than the rest of general aviation aircraft.

Existing FAR 36 noise restrictions probably can be met by new production aircraft. It is probable that these restrictions will be tightened to require reduced noise levels for the next generation of aircraft.

EPA emissions standards applicable to subsonic gas turbine engines of less than 8000 lb thrust will enforce a more stringent set of criteria for all engines manufactured after January 1, 1979. No current small turbofan or turbojet engine can meet these 1979 emission standards.

Approach

Program definition studies will be accomplished during FY 1975 as part of the R&T Base Technology program. The studies, to be performed by general aviation turbofan manufacturers will:

1. Analyze the applicability of large engine technology (noise/pollution) to general aviation turbofans.

2. Examine other factors significant in improving the applicability of small turbofans to general aviation.

A program plan will be included as part of the FY 1975 studies.

The Quiet, Clean, General Aviation Turbofan (QCGAT) program will be a contracted effort. A single contractor will be competitively selected for the experimental program. This program will include design, fabrication, assembly, and ground tests of the experimental engine. Further ground testing will be performed by NASA. Extensive use will be made of existing engine component technology and existing engine cores in order to hold down costs. Cost sharing will be explored.

There is no intention to proceed into a development program for a flight demonstrator engine.

SOURCE NOISE REDUCTION PROGRAMS

The objective of this program is to develop a noise source prediction capability for all categories of aircraft. This program involves the investigation and determination of the parameters that cause or influence the actual generation of noise emanating from aircraft, definition of noise sources and methods of reduction plus development of guidelines for changes to the engine and aircraft configuration required to minimize noise. Aircraft noise source elements are identified as follows:

- Turbo machinery
- Jet mixing
- Combustion/case
- Propeller and rotor
- Airflow surface interaction
- Lift augmentation
- Reciprocating engine
- Duct acoustic lining
- Aircraft configuration noise shielding

Source noise reduction research and development efforts can conveniently be described according to aircraft type: CTOL (transonic, subsonic and supersonic) and V/STOL. The schedule of major activities is described below and is shown in Table 1. A continuing effort to update and add to current capabilities is planned for both CTOL and V/STOL aircraft types through both in-house and contract activities. It is important that the latest technology in noise prediction and reduction techniques be readily available so that community exposures can be accurately estimated and noise control can be implemented by technologically practicable and economically reasonable regulations.

Core Engine Noise Control

The purpose of this project is to provide theoretical and expermental data to assist the designers in developing future aircraft

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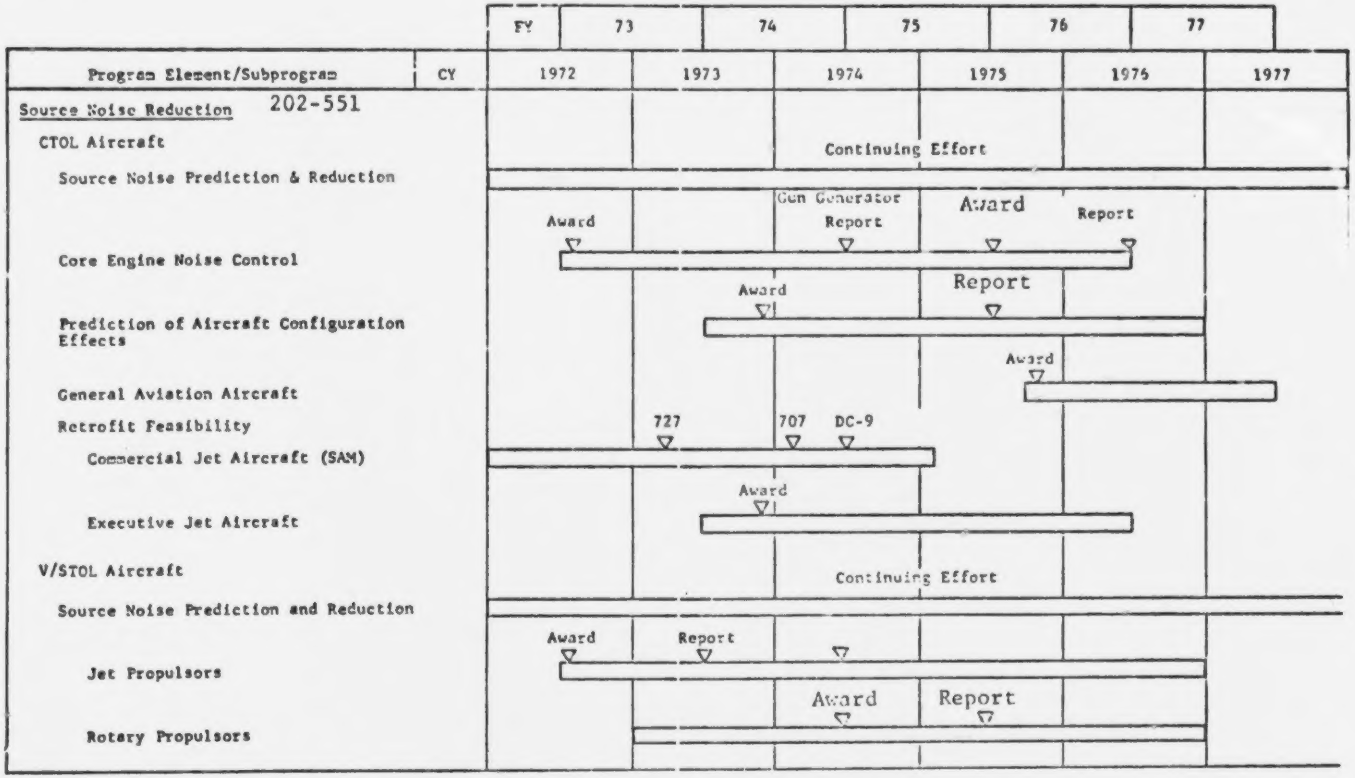
Table 1
AIRCRAFT NOISE ABATEMENT -- SOURCE NOISE REDUCTION
Program Schedule -- 1972-1977



capable of conforming to lower noise levels than are now required by FAR Part 36. The effort shall be directed to identifying, evaluating, and controlling the component noise sources inherent in the core engine (the gas generator) which establishes the limit of effectiveness of the current noise control state-of-the-art.

For the purpose of this project, core engine noise is defined as the noise produced by the gas generator portion of the gas turbine engine either solely or as influenced or amplified by the fan discharge, tail pipe, and/or any other portion of the exhaust system. Core engine noise shall be assumed to radiate only in the aft engine quadrant and its sources may be generated either upstream or downstream of the tail pipe exit plane. Core engine noise shall not be assumed to contain compressor generated noise radiating from either the engine inlet or fan exhaust ducting. Core engine noise, however, may include compressor generated noise transmitted downstream through the engine flow passages or fan generated noise enhanced by interaction with the core engine noise or gas stream.

Prediction of Aircraft Configuration Effects

The purpose of this project is to study the feasibility of use of aircraft configuration and engine placement to reduce noise propagation to the ground plus development of prediction procedures for configurations of practical interest.

General Aviation Aircraft

This project covers a survey and definition of the noise characteristic of all general aviation aircraft plus development of suitable noise prediction capabilities.

Retrofit Feasibility

- Current Commercial Jet Aircraft - The purpose of this project is to provide test data to assist in determining whether certain classes of turbofan propelled airplanes in the current fleet can be modified for meaningful noise reduction in a feasible manner. Feasibility relates to three key instructions contained in Public Law 90-411; that is, the noise abatement methods must be technologically practicable, economically reasonable, and appropriate for the particular type of aircraft, aircraft engine appliance, or certificate to which it will apply. The effort is directed to providing acoustical treatment, designed to conform to specified noise reduction goals. The acoustical treatment may be any hardware or mechanical device, applied either singly or in combination with the inlet and primary and secondary exhausts that will either absorb sound or otherwise effect a noise reduction at the FAR Part 36 measurement positions. Current retrofit programs for 727 aircraft will be completed in FY 1973; 707, DC-8, and DC-9 retrofit programs will be completed in FY 1974. The effort is directed to providing nacelles that are capable of being certificated. Results to date indicate that the retrofitted aircraft can comply with FAR Part 36.

- Executive Jet Aircraft - A retrofit feasibility program covering business jets is planned to follow the commercial retrofit project. The number of this type of aircraft is more than one-half that of the commercial fleet considered for retrofit and is growing rapidly. The purpose of this project is the same as given above for commercial jets. This program will draw upon knowledge gained and relate closely to the commercial jet program covered above. It is scheduled for completion in FY 1976.

V/STOL

V/STOL aircraft have propulsive lift systems that are distinctly different from conventional aircraft. Both rotary and jet propulsion systems are being considered. It is anticipated that V/STOL aircraft (including helicopters) will supply a major segment of the short haul transportation requirements in the near future. These aircraft, which are being considered for city center airports, may cause substantial increases in noise exposure for adjacent urban areas and also for suburban areas under the cruise path.

This effort is directed to identification, evaluation and controlling component noise sources inherent in V/STOL systems. Both jet propulsion and rotary propulsion systems will be studied. Prediction techniques will be developed.

OPERATIONAL NOISE REDUCTION PROGRAMS

The objective of this program element is the determination, investigation and measurement of significant factors which affect the transmission of noise from its source to the airport community. Elements are identified as follows:

- Aircraft Operational Procedures

- Atmospheric Parameters

Operational noise reduction is a continuing effort through both in-house and contract activities. Information developed will be used to update FAR Part 36, and in future noise rules. Projects apply to certification measurement and compliance.

The operational noise reduction program plan is presented in Table 2 and elements of the program are discussed below.

Noise Propagation Measurement and Evaluation

This program element will include studies of ground attenuation and of the importance of temperature and humidity measurements along the noise propagation path versus ground measurements only in correcting flyover noise measurements to standard conditions as currently required by FAR Part 36. This project could provide a refinement to FAR Part 36 and to improved accuracy in calculation of noise exposure areas.

Noise Measurement

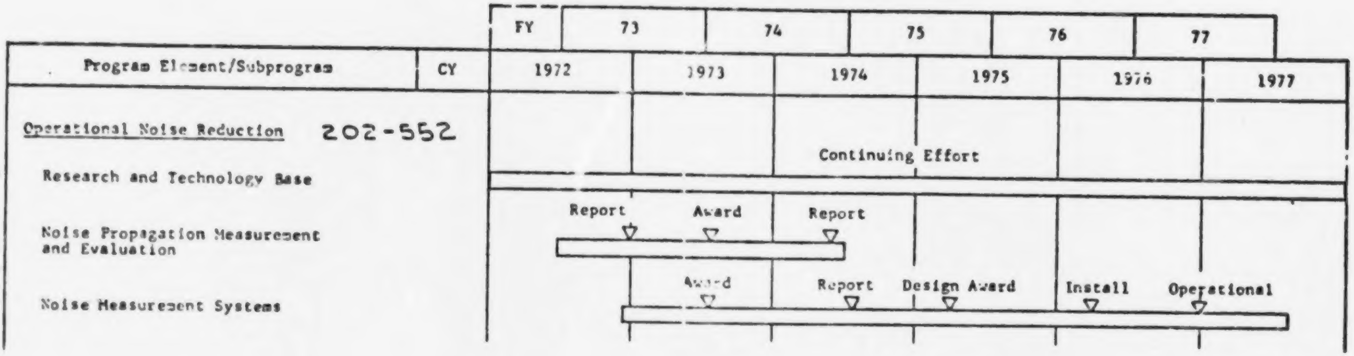
This program involves development of methods and equipment for noise measurement. The project objectives are to develop noise measurement systems with capabilities suitable for certification research, studies of noise abatement operating procedures long-range noise propagation, and community noise exposure. Certification measurement capability objectives include commercial subsonic and supersonic aircraft, general aviation including business jets, plus VTOL and STOL aircraft.

Increasing air traffic brings with it increasing complexity in airport noise patterns and as a consequence, more complete automatic and sophisticated measurements will be needed to determine the extent of the noise exposure. It would therefore be technologically advantageous to develop noise measurement systems capable of handling extensive measurement tasks, at greater accuracies, then the conventional systems.

NOISE EVALUATION AND RESPONSE

The objective of this program element is to determine the effects of noise on individuals and on the community as a whole; to develop methods required to predict the reaction of communities to noise resulting from varying numbers and types of aircraft; and to develop

Table 2
AIRCRAFT NOISE ABATEMENT -- OPERATIONAL NOISE REDUCTION, NOISE EVALUATION AND RESPONSE
Program Schedule -- 1972-1977



and/or refine acceptable yardsticks for evaluation and rating of various levels of aircraft noise. The program schedule is included in Table 2. Elements of noise evaluation and response are identified as follows:

- Noise exposure evaluation
- Community response surveys
- Subjective noise evaluation
- Psychoacoustic studies
- Noise exposure forecasting

Research to improve the technology base in this area is a continuing effort through both in-house and contract activities.

Current and planned projects are outlined below:

Noise Exposure

- Noise Evaluation and Community Response - The purpose of this project is the development of accurate and comprehensive noise evaluation criteria suitable for application to all CTOL aircraft including business jets and also suitable for application to V/STOL aircraft.

  Psychoacoustic laboratory and field tests will be conducted on response of human beings to aircraft sounds and noise evaluation measures developed for regulatory purposes by statistical correlation of test results. Investigations will be made of the significance of various annoyance factors such as multiple tones, speech interference, amplitude and duration of tones, doppler shift, low frequency effects, transient and impulse effects, and the rate of onset and intensity on duration.

- Noise Certification Criteria - Objectives cover development of techniques for noise measurement and analysis for use in certification of all aircraft categories, refinements to FAR Part 36 for CTOL aircraft plus development of criteria for business jets and V/STOL aircraft. Included are considerations of multi-segment or complex flight paths plus data acquisition and analysis systems. Work will include measurement and analysis of the aircraft noise and determination of procedures and equipment which will promote development of measurement and analysis standards.

SOURCE SONIC BOOM REDUCTION PROGRAMS

FAR Part 91.55 prohibits civil aircraft operations at true flight speeds greater than Mach 1 to prevent any sonic booms from reaching the ground. However, it is known that it is possible to fly up to speeds of Mach 1.4 without causing a sonic boom to reach the ground under certain conditions. Therefore, a demonstration was conducted during 1973 utilizing simulated operational techniques for long-range cross-country supersonic flights at Threshold Mach Number (Between 1.0 and 1.3) which theoretically did not generate sonic booms on the ground. This is Phase II of a four phase effort to develop a definition of the air and ground system requirements for successful supersonic Thresholds Mach Number operation. During 1974, based on Phase II results, conduct a SR-71 (YF-12) or F-111 transcontinental flight at Threshold Mach Number and not produce a sonic boom on the ground. Define and update the system requirements for boomless supersonic transcontinental flight during 1975 through 1977.

OPERATIONAL SONIC BOOM REDUCTION PROGRAMS

This effort will provide, during 1973, two prototype digital lightweight inexpensive sonic boom recorders for future field use to provide an improved capability to record signature data during sonic boom test and monitoring programs. Based on prototype tests results during 1974, obtain production units for operational test program during 1975. The FAA will also provide atmospheric sounding aircraft during joint FAA, NASA, USAF, and NOAA operational programs to obtain real-time atmospheric data (winds, turbulence, and temperature) for use in long-range Threshold Mach Number operational feasibility studies during 1973 through 1975, i.e., boomless transcontinental supersonic flights. Program schedules are in Tables 3 and 4.

Sonic Boom Atmospheric Effects

Studies are being conducted to identify measureable features of the atmosphere, both large scale and small scale, which cause statistical variations in sonic boom measurements. Attention will be given during 1974 through 1977 to establishment of a correlation between observed overpressure variability and local atmospheric conditions to provide a basis for prediction of that variability. The program will include theoretical and experimental work aimed at determining sonic

Table 3. SONIC BOOM--SOURCE SONIC BOOM REDUCTION, OPERATIONAL SONIC BOOM REDUCTION PROGRAM SCHEDULE -- 1972-1977

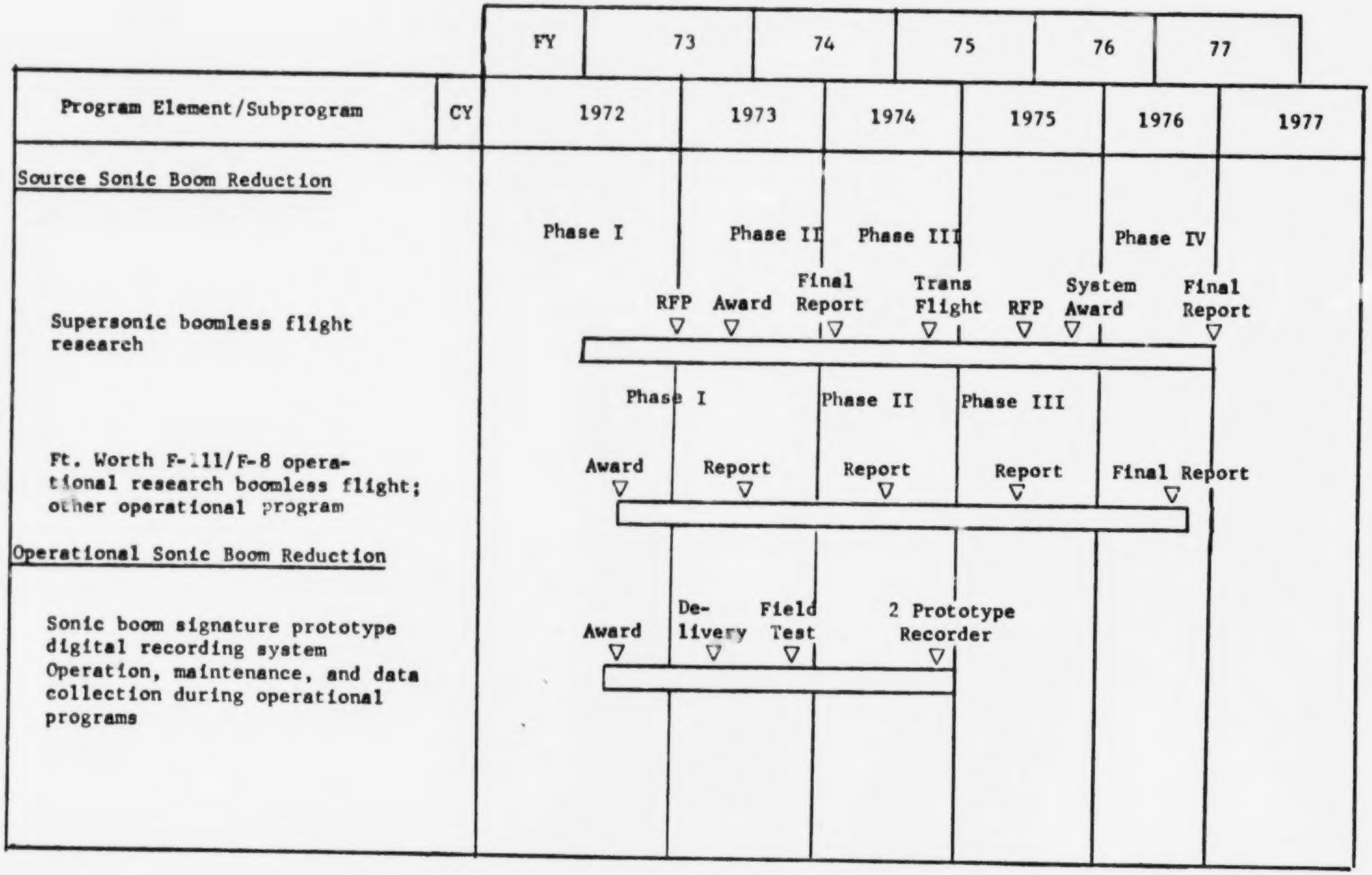
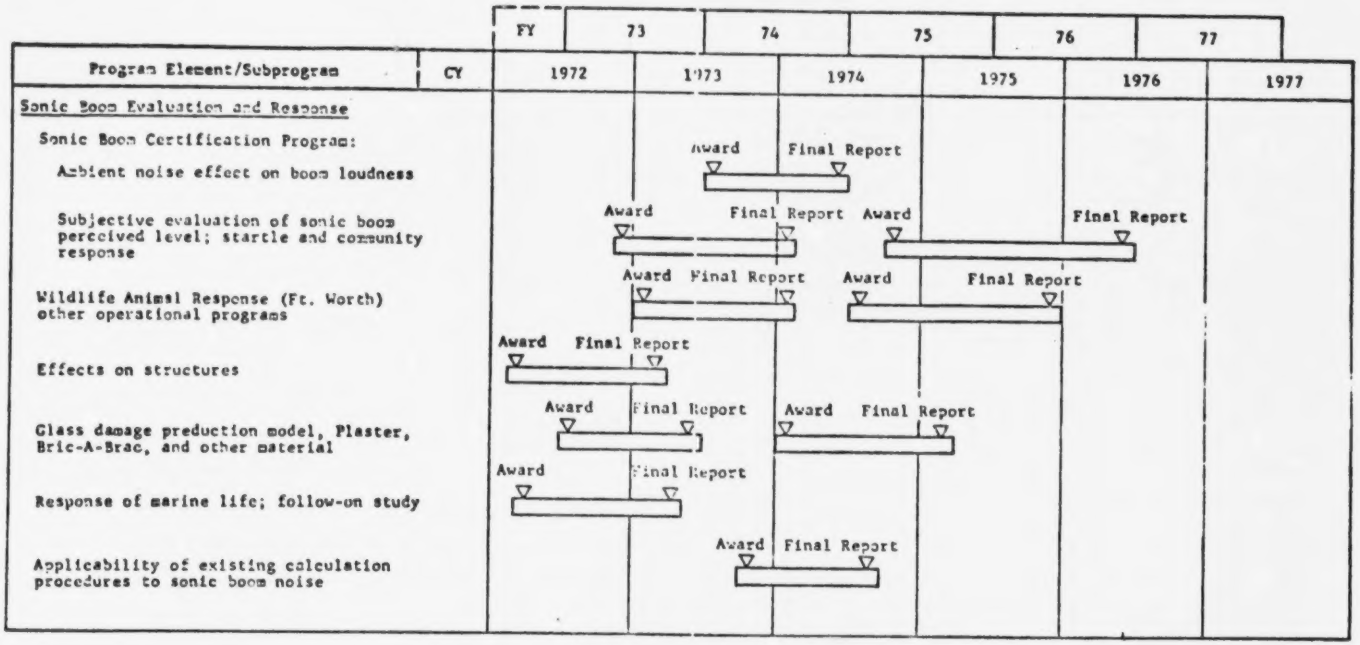


Table 4
SONIC BOOM -- SONIC BOOM EVALUATION AND RESPONSE
Program Schedule -- 1972-1977



boom pressure signatures associated with aircraft operations at or near Threshold Mach Number.

Sonic Boom Criteria

A sonic boom criteria research program is currently working to develop better technical and social criteria for sonic boom in accordance with Public Law 90-411 to form definitive guidelines upon which to base government and industry policies for both the design and regulation of supersonic and transonic commercial aircraft. The objective is to develop a consistent technical rationale based on the multiple technical and social criteria found from research that will assist in revising and updating administrative policies and decisions regarding certification limits and provide industry with a design window for supersonic operations.

Sonic Boom Effects on Structures

Structural damage due to moderate sonic booms has been primarily centered on damage to glass, plaster and bric-a-brac. Glass breakage is of primary importance. During 1974 and 1975 this work will develop sonic boom criteria in terms of equivalent response of windows to such natural forces as wind gusts, thunder and in terms of building codes applicable to window glass installation. This program will include flight programs, as well as simulator studies.

Test of Existing Noise Calculation Procedures Applicability to Sonic Boom

During 1973 and 1974, test the applicability of existing calculation procedures which scale annoyance and loudness reactions to steady state, time varying, and impulse noise. The object is to develop a simple method that would apply equally well to a variety of noises which would then be highly useful for multiple regulatory missions.

STATEMENT OF FREDERICK A. MEISTER, ACTING ASSOCIATE ADMINISTRATOR FOR POLICY DEVELOPMENT AND REVIEW, FEDERAL AVIATION ADMINISTRATION, DEPARTMENT OF TRANSPORTATION, BEFORE THE HOUSE COMMITTEE ON SCIENCE AND ASTRONAUTICS, SUBCOMMITTEE ON AERONAUTICS AND SPACE TECHNOLOGY, JULY 25, 1974, REGARDING AIRCRAFT NOISE ABATEMENT EFFORTS.

Thank you for the opportunity to appear before you today, Mr. Chairman. I am Frederick A. Meister, FAA Acting Associate Administrator for Policy Development and Review. Appearing with me today are Charles R. Foster, Director of the Department of Transportation Office of Noise Abatement, and Richard P. Skully, Director of the FAA Office of Environmental Quality.

In passing the Noise Control Act of 1972 the Congress declared it to be the policy of the United States "to promote an environment for *all* Americans free from noise that jeopardizes their health or welfare." The Congress further authorized and *directed* Federal agencies to carry out the programs within their control in such a manner as to further that declared policy of the United States "to the *fullest* extent consistent with their authority under Federal laws administered by them." Section 7(b) of the Noise Control Act directs the Administrator of the Federal Aviation Administration to prescribe such regulations as the FAA may find necessary to provide for the control and *abatement* of aircraft noise "in order to afford *present* and future relief and protection to the public health and welfare." (emphasis added).

By statute it is the FAA which has the responsibility, after consultation with the Secretary of Transportation and EPA, to prescribe standards for measuring aircraft noise and for prescribing regulations for the control and abatement of aircraft noise.

Mr. Chairman, the FAA is taking this Congressional mandate seriously and is in the process of implementing an aggressive program to control and abate aircraft noise. As evidence of our resolve to help achieve a better environment for all Americans, steps have been taken to double the size of the FAA Office of Environmental Quality. In addition, the Administrator has recently released a draft FAA Five Year Environmental Program which defines FAA environmental policy and delineates a five-year program designated to implement that policy.

Three parts of our overall noise abatement program relate to the design and operation of aircraft.

First is the imposition of maximum noise limits for all types of aircraft to insure that individual aircraft noise levels will not increase as newer, more powerful aircraft types are designed, and to insure

Pages 172, 173 and 174 are blank.

that the best available noise reduction technology is included in the design of all new aircraft. In 1969, the FAA promulgated Federal Aviation Regulation Part 36 which put a lid on the escalation of aircraft noise levels of new subsonic turbojet transport aircraft. In 1973, Part 36 was amended to include newly produced aircraft, including those of older designs not previously covered. As you know, we have proposed a retrofit regulation to cover all large civil transport aircraft, requiring that older models not previously covered be modified to lower their noise levels to at least Part 36 limits. That proposal will be the subject of detailed discussion in a moment. We will soon promulgate a regulation limiting the noise levels of propeller-driven airplanes. The final Environmental Impact Statement for this regulatory action is in the process of being forwarded to the Council on Environmental Quality. We have solicited public reaction to our proposal to establish noise limits for short haul aircraft, and we are preparing a proposal for noise limits for civil supersonic aircraft. In this step-by-step manner, we are setting maximum noise limits for all categories of civil aircraft.

The second step in our program involves the use of approach and departure operational procedures which will reduce noise impact around our airports. The FAA views the control of aircraft noise through the use of operational procedures to be a promising and practical means for obtaining early noise relief. We have for many years been experimenting with takeoff and approach procedures, passive and dynamic preferential runway procedures, noise abatement routing, and terminal area handling of aircraft to achieve noise control.

Noise abatement takeoff operating procedures designed to provide maximum separation between aircraft and the communities overflown were developed jointly by FAA and ATA and are now in wide use.

Noise abatement approach operating procedures developed jointly by FAA and NASA include a two-segment glide slope which provides noise reduction by use of lower power settings and higher altitudes during the initial phase of an approach. A few airlines have been using two-segment approaches safely and efficiently for over one year during VFR weather conditions. The joint NASA/FAA research on two-segment approaches has reached the point where in-service operational implementation is progressing under instrument flight rule (IFR) conditions as well. In fact, a major airline has conducted in-service operations for NASA with a B-727 aircraft under VFR and IFR weather conditions. NASA is currently working with United Air Lines on two-segment approaches utilizing Douglas DC-8 aircraft. The FAA has recently issued an Advance Notice of Proposed Rule Making seeking advice and comments on this two-segment approach procedure. I will give you a rundown of the comments received to date later on.

Another means of maximizing aircraft to ground separation distances to provide community noise relief is to change allowable minimum altitudes. The utilization of higher minimum altitudes as a means of achieving noise reduction has been implemented and is providing significant noise relief. An Advisory Circular was published in August 1972 to deal directly with VFR flight near noise sensitive areas. This has resulted in pilots making VFR flights near recreational and park areas, churches, hospitals, schools, and similar areas at higher altitudes than previously flown and permitted by regulation in order to reduce aircraft noise impact on the ground.

The third step in our program, oriented more for the future, is the progressive reduction of present permissible noise levels. We are not content with present noise levels -- we are striving constantly to improve the state-of-the-art to lower these noise levels. Part 36 limits have now been in effect four and one-half years, and we are giving serious consideration to proposing a lowering of those limits to increase their stringency. We will of course continue to support effective research to develop and demonstrate just what future reductions may be feasible. And so, in brief, this covers that portion of our aircraft noise abatement program relating to the design and operation of aircraft.

I would like to turn now to a discussion of the retrofitting of the current commercial jet fleet to meet FAR 36 standards.

The technical development of means for quieting the present fleet has been underway for more than six years. This joint industry-government effort has resulted in the expenditure of well in excess of $100 million. The major steps taken in this program were as follows: first, an early NASA program provided proof of the technical concept of using sound-absorbing materials in nacelles, which I shall refer to as SAM, to control aircraft noise; second, an FAA nacelle jet suppression and flight test program was conducted; third, feasibility studies and flight demonstrations were made, followed by actual certification of the Boeing 727 and 737 and the Douglas DC-9; and, finally, a decision was made that we were ready to initiate formal regulatory action as required by law. On March 27, 1974, a Notice of Proposed Rule Making was published which, if adopted, will provide the means of assuring that all currently available acoustic technology is applied to in-service commercial aircraft. The rule would require that subsonic turbojet aircraft, having maximum weights of 75,000 pounds or more, to conform to Part 36 noise levels by not later than July 1, 1978. Behind this proposed rule is our conviction that utilizing the technology of sound absorbing material in engine nacelles is available now for providing additional, significant relief from aircraft noise.

Before we embarked upon this rulemaking procedure, Mr. Chairman, we had to assure ourselves that the SAM nacelle treatment would provide meaningful relief, that is, we were looking for a reduction in noise levels which would be sufficient to significantly reduce annoyance levels for persons living near airports. I would like to point to three important items of evidence which in my view go a long way toward dispelling any doubts that the SAM retrofit program would provide that meaningful relief.

First, it is a fact that today's airport neighbors notice and appreciate the reduced noise levels of the new wide bodied aircraft. These aircraft meet the same Part 36 noise levels as the older aircraft would meet with the SAM retrofit.

Second, a joint FAA-Boeing Company project, which culminated in May 1973 flyover demonstrations for members of Congress and the public at Dulles International Airport, demonstrated that takeoff noise reductions of 11 EPNdB and approach noise reductions of 15 EPNdB were achievable using nacelles quieted with sound absorbing material on a JT3D-powered Boeing 707 aircraft. There was general agreement among those witnessing the flyovers of a B-707 treated with sound absorbing material in a configuration capable of being certificated and a B-707 without such material, that the noise reduction was highly significant and clearly perceivable.

Third, a NASA-sponsored approach noise study conducted by Professor Paul N. Borsky of the Columbia University Noise Research Unit has concluded that significant reductions in annoyance resulted from the use of exposure to synthesized nacelle treatments equivalent to a JT8D-powered Boeing B-727 with the SAM treatment as compared to a standard B-727 aircraft. Professor Borsky, of Columbia's School of Public Health, College of Physicians and Surgeons, is one of the world's leading experts in assessing community response to aircraft noise. He used test subjects living in the vicinity of Kennedy International Airport. Significantly, there was a 50% reduction in the number of test subjects who had expressed highest annoyance to the standard Boeing 727 aircraft as compared to the acoustically treated B-727. This 50% reduction was achieved with a difference of 6 EPNdB between the two aircraft. We would anticipate a very meaningful response for the Boeing 707 mentioned a few moments ago relative to the Dulles flyover demonstrations.

I would also like to point out that in addition to the SAM retrofit it is possible to tailor approach and departure procedures to achieve even greater relief than can be achieved by SAM. The two-segment approach procedure and a power reduction on takeoff are examples of procedures we are investigating.

Next I would like to give you a rundown of the comments received on the fleet retrofit NPRM and the two-segment approach Advance NPRM. Nearly 600 comments were received on the retrofit NPRM, of which some 500 were from private citizens and citizen groups. The overwhelming majority of citizens and citizen groups were for immediate promulgation of the final rule. With regard to the industry, the Air Transport Association and commenting air carriers expressed total opposition to the proposed rule as written. Particular concern was expressed over the possibility of performance penalties and the amount of benefit considering the price tag. Regarding the manufacturers, the Aerospace Industries Association of America and the Boeing Company, while not opposing the rule as such, expressed little enthusiasm and support for an immediate go ahead, while the Douglas Aircraft Company was firm in its opposition to the rule. The international carrier community, represented by IATA, and several foreign governments expressed opposition for several reasons. A further discussion of the international reaction will be given a little later.

U.S. Airport Operators, whose jurisdictions are facing a total of some $4 billion in aircraft noise damage claims, strongly endorsed and urged immediate adoption of the rule. From this group we heard from some 25 city, county and state airport or transportation authorities plus the airport operator associations.

Private aircraft owners and operators did not, in general, support the rule, expressed doubt that SAM would produce appreciable relief and expressed concern over the program's expense.

We also heard from the Department of State, which expressed concern over unilateral U.S. action, and the Environmental Protection Agency, which concluded that the proposed regulation represents a substantial step in the right direction.

By the way, with regard to comments received on the two-segment approach Advance NPRM, the line-up was roughly the same. Private citizens, citizen groups, city governments and airport operators favored adoption of the two-segment approach. Those opposed included ALPA, AOPA, NBAA and the International interests. Those expressing strong reservations were ATA, Boeing and GAMA.

There are two basic problem areas associated with putting the retrofit rule into effect, namely, the international implications of the rule and the problem of how the retrofit program should be financed. I would now like to discuss these two problem areas.

The retrofit NPRM applies not only to U.S. registered aircraft, but also to foreign civil subsonic turbojet powered aircraft of 75,000 pounds or more that land or takeoff in the United States. The inclusion of foreign civil aircraft was considered essential because the airports having the most serious noise problems are generally those served most frequently by foreign operators. The bulk of comments received from the international community took strong exception to the proposed rule on the basis that it amounted to unilateral action in an area which ICAO should coordinate. The Department of State expressed concern over possible proliferation of conflicting standards affecting international civil aviation if the United States took unilateral action without either reaching agreement through ICAO, or at least by coordinating plans with other major civil aviation countries.

The international problems associated with the rule are difficult, but their impact has not been ignored. In fact, last month Administrator Butterfield met in Montreal with ICAO President Binaghi, the Secretary General of ICAO, a number of the members of the Secretariat, Council members and Air Navigation Commissioners. The Administrator made it clear to Dr. Binaghi that it was not the desire of FAA to act unilaterally and that we continued to support a multilateral approach. He did not, however, commit the United States to multilateral agreement with respect to the retrofit requirement because we are still considering foreign aircraft operating into the United States for inclusion in our aircraft noise reduction actions. We are hopeful that our actions in this area will stimulate multilateral action similar to the multilateral action which followed the issuance of Part 36.

The question of financing the retrofit program is central to a decision to put the proposed rule into effect. We know the program will be expensive, some $600 to $700 million to retrofit the existing fleet. I believe this issue, more than any other, accounts for the industry's lack of support.

In issuing the NPRM we solicited recommendations for financing the cost of the retrofit program. A number of suggestions were made, including use of the Airport and Airways Trust Fund, long term, low interest government loans to private operators, surcharges on passenger tickets and cargo way bills and increased air fares to allow the carriers to recover costs.

We have reviewed the various financing alternatives, and, while we have reached no conclusions on the shape of a final plan, some tentative decisions have been made. First we are opposed to direct Federal funding; we believe, instead, that the users of our air transportation system, the passengers and shippers, should, as a matter of principle, pay for the costs of retrofit. At present we believe that the best means to achieve this goal would be the establishment of a special fund, supported by nominal enplanement and cargo way bill surcharges proportionate to the aircraft modification costs for each segment of the air carrier industry. Such a plan would cover only domestic operations; the international operations of U.S. carriers would have to be handled separately.

Mr. Chairman, NASA has played a vital role with us in the abatement of aircraft noise. Through the Joint DOT/NASA Office of Noise Abatement we have an effective vehicle for assuring an integrated research and technology program. We have both supported and worked with EPA in its role in coordinating noise research as specified in the Noise Control Act. The three agencies have worked closely together at the staff and Administrator levels to marshall the Federal aircraft noise abatement effort. For example, this Monday I represented Administrator Butterfield, who was appearing before the Senate Appropriations Subcommittee, in a meeting with Undersecretary Barnum, Administrator Fletcher and Assistant Administrator Strelow representing Administrator Train, to review our efforts, particularly with respect to the refan program and FAA's regulatory actions. The DOT/FAA position expressed at that meeting was that there is more than an adequate technical and economic basis for a decision at this time to proceed with regulatory action. Assuming that all objectives of the refan program would be achieved, the cost-effectiveness picture, in our view, will be unchanged.

In considering the relative merits of SAM versus refan in our rulemaking efforts, we have considered the following factors as being of primary significance.

First, the SAM modification offers the earliest meaningful relief. With reference to time, we believe that completion of a refan retrofit program would be at least three years behind completion of the SAM retrofit program.

Second, the refan program does not apply to the noisiest aircraft in the fleet, the JT3D-powered Boeing 707 and Douglas DC-8.

Third, refan represents at best a promise of future relief since the present program is limited to flight testing of the Douglas DC-9 and ground testing of the Boeing 727. No work is presently being done with the JT8D-powered Boeing 737. Work on the B-737 terminated with the Phase I design effort. Additional work and funding would be required for the refanned B-737 to be a candidate for any future rulemaking.

Fourth, the refan program is considerably more costly than the SAM retrofit program. For example, the SAM retrofit of the entire fleet is estimated to cost approximately $600 to $700 million for investment with total program cost over the remaining life of the modified aircraft approaching $1 billion. In comparison, the combination program of using refan for JT8D-powered aircraft and the use of SAM for

JT3D-powered aircraft would cost approximately $2.8 billion for investment with total program cost of $5 billion. In terms of one aircraft, the Boeing 727, the cost of refanning would be roughly eight to ten times the cost of using the SAM retrofit. The B-727 with the SAM modification provides the same noise reduction on approach as the refanned B-727.

The relative cost-effectiveness of the two aircraft modification programs has, as you know, been a part of our 23 U.S. airport analysis. This effort, begun some time ago, provides the DOT/FAA with information needed to evaluate a wide range of aircraft and airport noise abatement alternatives. We have completed the 23-airport study, and the cost-effectiveness results have not changed substantially from those reported to you last December on the basis of the first six airports.

These results are presented in terms of (1) airport neighbors subjected to two levels of noise exposure, (2) land areas around the 23 airports impacted by airport noise, and (3) effective changes in the noise exposure index. All of these indicators provide the same conclusions: first, the SAM program is significantly more cost-effective than the potential SAM/Refan program; and, second, effectiveness will be obtained earlier with the SAM program.

For example, with respect to the people removed from the noise exposure areas of NEF 30 and NEF 40, and looking forward to 1987, the end period of the study, we find that for an expenditure of $1 billion for SAM, we remove 125,000 of the 300,000 people that would be residing in the NEF 40 area. For an expenditure of $5 billion for refanning the JT8D and SAMming the JT3D, 220,000 people would be removed. An additional expenditure of $4 billion dollars for the refan/SAM program would remove 95,000 people from the NEF 40 area. In the NEF 30 contour, the $1 billion SAM program will remove 600,000 of the 2,700,000 people, whereas the $5 billion refan/SAM program will remove 1,900,000 people.

In brief, the results of this study are consistent with our earlier conclusion that the action proposed in our Notice of Proposed Rule Making on March 27, 1974, will provide the earliest meaningful relief to airport neighbors through a program which is technologically available and economically reasonable. I am submitting a detailed Information Brief describing the results of this study for the record, Mr. Chairman. And, Mr. Foster is prepared to provide a brief summary of this study if you desire.

With regard to the goal of 10 EPNdB reduction per decade identified in the CARD study, we feel that for this first decade we will be able to achieve the goal, generally speaking. Looking ahead to the next and succeeding decades, however, we are reaching the point of diminishing returns with foreseeable technology. We will continue to assess developing noise reduction technology with the idea of keeping our regulatory program apace.

In concluding, I would like to make the following remarks.

Noise is a major problem impeding further growth of the air transportation industry. Aircraft noise has brought increased pressure to limit flight operations and restrict flight paths as well as to impose night curfews. Airport operators are faced with aircraft noise related suits involving potential multimillion dollar judgments.

Congress recognized this serious impediment to air transportation industry growth and the serious implications regarding the health and welfare of the Nation's population when it passed the Noise Control Act of 1972.

We have developed a retrofit program which offers great promise of the earliest relief which Congress mandated be afforded. There has been some concern expressed by Congressional Committees about our moving ahead with the retrofit rule prior to obtaining the final results of the refan test to be completed next year. We of course fully appreciate these views, and before publishing a final rule we will present to those committees our reasons for moving forward. We feel confident that we will have their support for any action that we take to advance our noise abatement program in a cost-effective way. Our present posture is to continue with the regulatory process to work toward a resolution of the difficult problems associated with the proposed rule, such as the financing and international aspects. Only when we are satisfied that we have solved these problems will we be in a position to make a final decision on the rule.

Thank you for your attention to this rather lengthy testimony, Mr. Chairman. I and my associates are available to answer any questions you may have.

The DOT has university grants for fundamental studies in noise suppression. These studies are briefly described with funding indicated.

1. University of Southern California Contract
   DOT-OS-000-2
   Title: Modeling Noise

   An extremely elaborate and quiet facility has been constructed to isolate the jet noise sources. The elimination of upstream and outside noise contamination will allow for accurate measure of the noise from the jet alone by use of a sophisticated noise collection reflector-microphone combination connected to a traversing device. The sources or distribution contributing to the overall jet noise is thus determined. The large scale structure of jet turbulence is being investigated as a possible major contributor to jet noise.

   Funding: (Thousands of Dollars)

FY 73	FY 74	FY 75	FY 76
75	75	50	50

2. University of Syracuse New York Contract
   DOT-OS-20094
   Title: Noise Reduction from Supersonic Jet Flow with Co-Axial Jets

   The objective of this program is to study the mechanism of jet noise reduction in co-axial jets when the individual jets are operating under unique conditions that lead to a strong shock formation and hence to subsonic flow conditions a small distance outside the nozzle exit. Under these conditions the jet noise is significantly reduced below that condition of operation that does not form into a strong coalesced shock. The specific objectives will be to (1) verify the existence of the minimum noise condition for larger jets and to study the scaling laws, (2) establish the effects of temperature on noise reduction for co-axial jets, and (3) study those phenomena with 2 and 3 co-axial elements.

   Funding: (Thousands of Dollars)

FY 73	FY 74	FY 76
75	75	75

3. California Institute of Technology Contract
DOT-OS-20197
Title: Jet Combustion Noise

The purpose of this study is to investigate experimentally and theoretically the noise generated by combustion inhomogeneities as they pass through nozzles or turbine buckets. Theoretically, it has been shown that a pressure disturbance gets amplified on passing through a nozzle, likewise a temperature oscillation in the chamber leads to noise generation and it too gets amplified on passing through a nozzle or turbine. These factors will be studied.

Funding: (Thousands of Dollars)

FY 73	FY 74	FY 75
147	50	50

4. Massachusetts Institute of Technology Contract
DOT-OS-30011
Title: Acoustic Material Research

The purpose of this study is to determine the characteristics of acoustic liners in ducts that have an added mechanical inertance that acts to lower the natural frequencies of Helmholtz resonators with a given backing depth thus allowing for the absorption of low frequency acoustic energy in the duct. This development is important for application to problems involving the reduction of low frequency noise from fans and combustion.

Funding: (Thousands of Dollars)

FY 73	FY 74	FY 75
33	35	35

5. The University of Texas at Austin Contract
DOT-OS-4117
Title: Effects of Non-Linearity on Jet Noise Propagation

The purpose of this contract is to study the non-linearity effects in the propagation of intense noise. Non-linearity causes an increased attenuation of the noise, a spectral redistribution of the energy, and decreased cross correlation between the source and receiver waveforms. The question is posed as to whether these effects are important for jet noise propagation. Specific work will include conversion of the already existing plane wave analysis into a spherical spreading one; use of the modified analysis to predict the propagation distortion for noise from an actual intense jet noise source.

Funding: (Thousands of Dollars)

FY 74	FY 75
18	20

6. North Carolina State University Contract
DOT-OS-40056
Title: On the Origin of Combustion Generated Noise

The objective of the program is to present a theory capable of explaining the observed characteristics of combustion noise whose validity does not hinge on the assumptions employed and on the particular situation considered. Starting from the exact multi-fluid equations of a reacting gas mixture, the mechanism of combustion generated noise for open and confined flames is identified. The derivation parallels the procedure employed by Lighthill and Curle and does not depend on simplifying assumptions. It is shown that the pressure fluctuation is a sum of two terms. The first is proportional to the overall density fluctuation and the second is a linear combination of the density fluctuations of the various species. At present, a reliable estimate of combustion noise cannot be made; a complete understanding of the problem first requires the identification of the sources of the noise due to combustion and scaling laws and the effects of confinement on the propagation.

Funding: (Thousands of Dollars)

FY 74	FY 75	FY 76
25	30	25

7. General Electric Company Contract
DOT-OS-30034
Title: High Velocity Jet Noise Source Location and Reduction Program

The overall objective is to investigate the promising suppression concepts that will result in the greatest noise suppression with the least degradation of performance over flight speed ranges of interest for the potential types of engine cycles. The theoretical understanding of these more complex nozzle concepts presents a great challenge and is a fundamental part of the objective of this program.

The detailed investigation of the basic phenomena which affect the source locations, source strength, and noise reduction potential of high velocity jet noise is directed towards the following program objectives:

- Investigation of the aerodynamic and acoustic mechanisms of various jet noise suppressors for subsonic and supersonic jets, including scaling effects.
- Analytical and experimental studies of the acoustic source distribution in such suppressors, including identification of source location, nature and strength, and noise reduction potential.
- Investigation of in-flight effects on the aerodynamic and acoustic performance of these suppressors.

The results of these investigations will lead to the preparation of a prediction guide report for predicting the overall characteristics of suppressor concepts, i.e., for models, full-scale static, and in-flight conditions, as well as a quantitative and qualitative analytical prediction of the phenomena involved.

The work effort in this program is organized under the following major categories:

Task 1 - Activation of Facilities and Validation of Source Techniques

Task 2 - Theoretical Developments and Basic Experiments

Task 3 - Experimental Investigation of Suppression Principles

Task 4 - Development and Evaluation of Techniques for "In-Flight" Investigation

Task 5 - Investigation of "In-Flight" Aero-Acoustic Effects on Suppressed Exhausts

Task 6 - Preparation of Noise Abatement Nozzle Prediction Guide Report.

See Figures 14 and 15 for funding and schedule.

[illegible] VELOCITY JET NOISE SOURCE LOCATION AND REDUCTION

● OVERALL PROGRAM PLAN

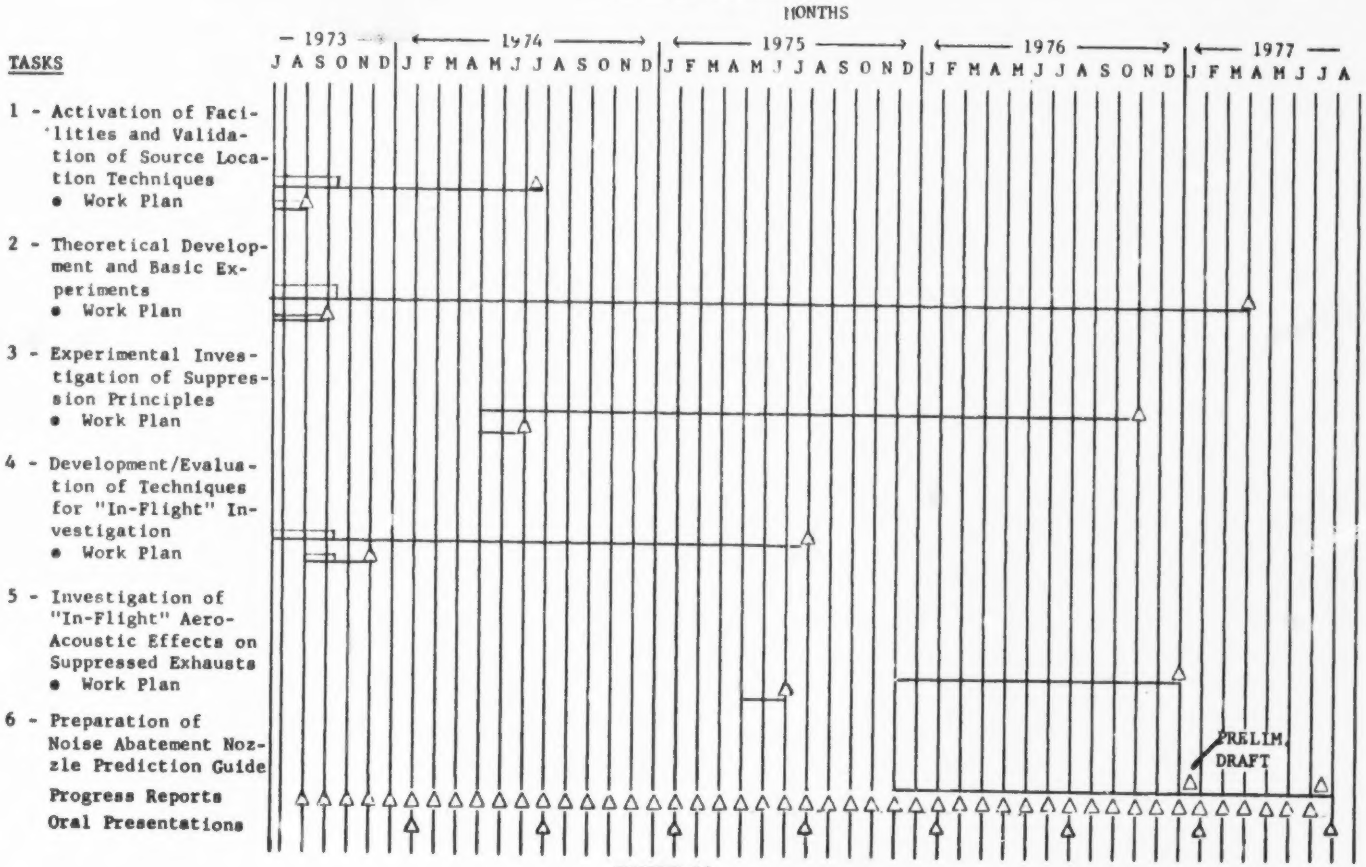


FIGURE 14

ESTIMATED TOTAL PROGRAM EXPENDITURE SCHEDULE

- ALL TASKS (1 - 6)
- CUMULATIVE DOLLARS
- COST INCLUDES IR & D/GA, ETC.

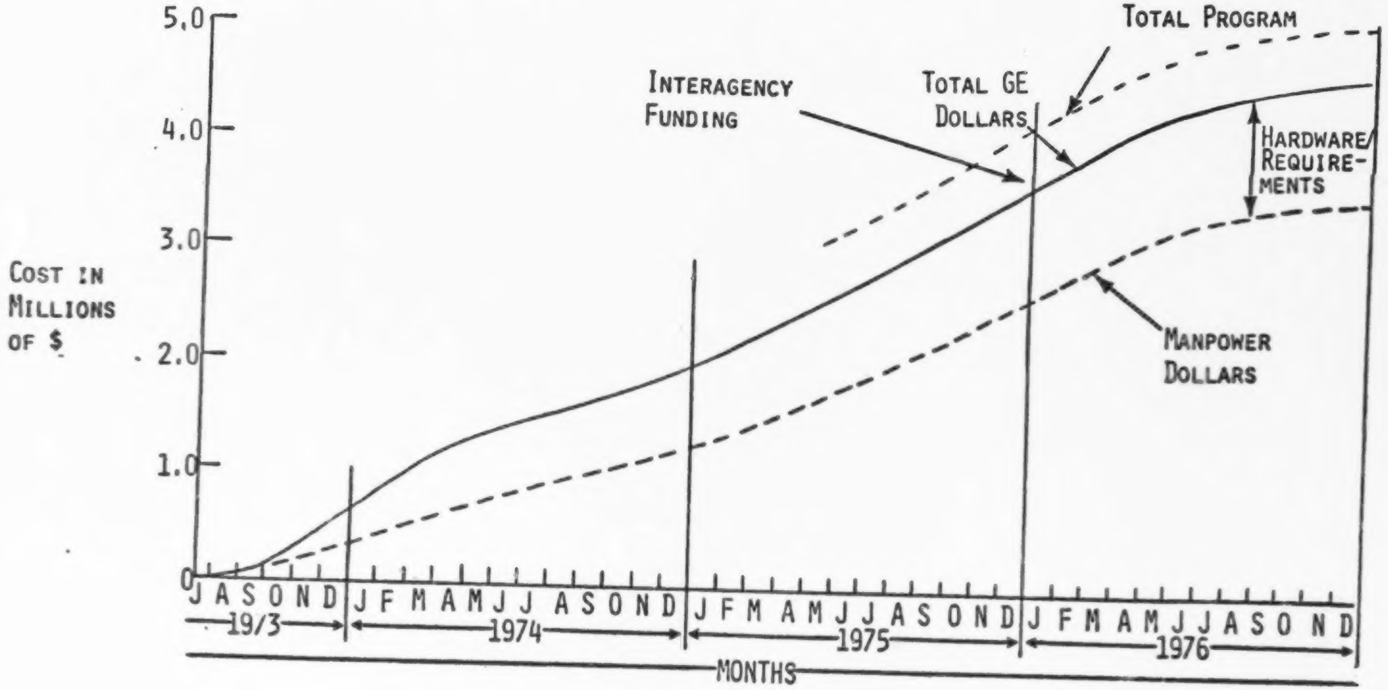


FIGURE 15

8. Virginia Polytechnic Institute Contract
DOT-OS-50047
Title: Suppression of Multiple Pure Tones

This is a program to evaluate an advanced acoustic concept for the suppression of multiple pure tones from supersonic jet engine fans. The concept is based on the dispersion of waves by acoustically treating the duct walls to inhibit the exchange of energy among the harmonics and to counteract the steepening of the waves due to non-linearity. A detailed parametric study will be performed to determine the optimum linear characteristics.

DOD JET EXHAUST NOISE PROGRAMS

Department of Defense
Air Force
SUPERSONIC JET EXHAUST NOISE-PRESSURE MODEL
Bolt Beranek & Newman Inc.

Contract F33615-71-C-1661
Project 3066, Task 14,
Work Unit 02
7/72 to 6/73
Funds $164,000

The overall objective of this program is to develop the technology base necessary to significantly reduce aircraft propulsion system noise with minimum associated performance and weight penalties. The specific technical objectives of this effort are (a) to assess the advantages and disadvantages of various competing mathematical models used to explain the supersonic jet noise generation process with particular emphasis on the Ribner/Meecham fluctuating pressure model; (b) to determine the relative importance of the various jet noise generation mechanisms for the range of operating conditions typical of the B-1 system; (c) to experimentally demonstrate the advanced instrumentation techniques required to verify the accuracy of the Ribner/Meecham fluctuating pressure model.

This program involves a comprehensive investigation of all relevant mechanisms of noise generation and emphasized the interrelationships between acoustics and engine cycles and between acoustics and exhaust jet aerodynamics. The experimental investigation features the use of unique transducers to relate the exhaust fluctuating aerodynamic pressures to the radiated noise. A large-scale, high temperature (3000° F) free jet facility will be used to conduct aero/acoustic experiments. This facility makes it possible to compile a comprehensive and exhaustive catalog showing the inter-relationship between nozzle mean and fluctuating aerodynamic and acoustic properties of supersonic jet exhausts.

SUPERSONIC JET NOISE INVESTIGATION - VELOCITY MODEL
General Electric

Project 3066, Task 14,
Work Unit 03
Funds $164,000

The overall objective of this program is to develop the technology to significantly reduce supersonic aircraft propulsion system noise with minimum associated performance and weight penalties. Emphasis is placed on afterburning and non-afterburning supersonic jet exhaust systems with operating conditions typical of supersonic transport (SST) and long range strategic (B-1) aircraft propulsion systems. The specific technical objective of this research program is to develop a comprehensive mathematical model capable of providing aero/acoustic design

Pages 194, 195 and 196 are Blank.

data to be used in the development of future supersonic jet exhaust noise suppressors.

SUPERSONIC JET NOISE
INVESTIGATION - DENSITY MODEL
Lockheed, Georgia

Project 3066, Task 14
Work Unit 04
Funds $199,000

The overall objective of this program is to develop the technology to significantly reduce supersonic aircraft propulsion system noise with minimum associated performance and weight penalties. The specific technical objectives of this program are to numerically solve the applicable turbulence and acoustic theories which describe jet noise generation and radiation for the subsonic and fully-expanded supersonic flow regime and to measure the necessary turbulence and acoustic parameters in order to verify the numerical predictions or to supply data to the turbulence/noise theories as necessary.

GENERAL ELECTRIC/LOCKHEED
Contract DOT-AS-20099 / AF Contracts F33615-73-C-203 1/2
Title: Supersonic Jet Noise (Analytical Model)

The overall objective of this program is to develop a fundamental understanding of the mechanisms of jet noise generation. This phase of the work is limited to sound single nozzles in contrast to the complex nozzle configurations of suppressor types. The specific technical objectives are to numerically solve the applicable turbulence and acoustic theories which describe jet noise generation and radiation for the subsonic and fully-expanded supersonic flow regime and to measure the necessary turbulence and acoustic parameters in order to verify the numerical prediction or to supply data to the turbulence/noise theories, as necessary. The program comprised of an experimental and theoretical effort to predict noise from subsonic and supersonic jets with particular emphasis on the turbulent mixing region. Development of promising optical techniques to measure necessary turbulence spectra intensity, and scales is also included. The objectives are intended to lead to a unified theory of jet noise. The work will be performed in four phases:

Phase I - Through review of competing mathematical models.

Phase II - Detailed investigation - relate flow field to acoustic.

Phase III - Investigate effects of upstream perturbations.

Phase IV - Correlation of all results into unified theory.

Contracts are with Lockheed Georgia and General Electric in Cincinnati. This work was started in 1971 and will be completed in March 1975. Total funding by DOT is 1.3 million in the following schedule of expenditure.

	FY-73	FY-74	FY-75
DOT	$ 425,000	$ 625,000	$ 250,000
DOD/Air Force	$ 125,000	$ 205,000	$ 60,000

JET NOISE REDUCTION FOR MILITARY RECONNAISSANCE/SURVEILLANCE AIRCRAFT Bell Aerospace Corporation	Project 3066, Task 14, Work Unit 005

The objective of this program is to evaluate and experimentally demonstrate a unique quiet propulsion concept for advanced quiet aircraft systems. The performance and acoustic characteristics of the total propulsion system will be assessed under this effort.

DOD AIRFLOW SURFACE INTERACTION PROGRAMS

Department of Defense	DF032080
Air Force	Contract AF-AFOSR-2068-71
NOISE CONTROL BY LIQUID VAPORIZATION	7/73 to 6/74
California Institute of Technology	Funds $31,220
School of Engineering	

Strategic bombardment, tactical operations, and logistic support are AF functions which require the use of high performance flight vehicles. The operation of such vehicles produces intense noise from sources associated with propulsion systems. Because of a lack of a basic understanding of the physical behavior of sound and the interaction of sound with the fluid medium it is traveling through, rational noise control and avoidance is difficult. This noise can cause degradation in human performance, reduced reliability of structural and equipment subsystems and increased maintenance. The proposed research will investigate the behavior of high intensity sound as it interacts with liquid droplets. Specifically, an analysis will be made of nonlinear acoustic disturbances in a heterogeneous gas-liquid mixture where transition between the two phases constitutes an important element of the problem. Particular stress will be given to the wave steepening beyond the plane of generation, to the attenuation of duct modes and to the effect of phase change attenuation on acoustic fields resulting from gas-dynamic interaction with sharp edges.

AERODYNAMICALLY GENERATED SOUND

University of Toronto

Project 9781, Task 02
Work Unit 001

This research is directed toward developing a comprehensive physical model of jet noise which covers generation, convection, refraction, and spectrum properties. Research is being conducted in the areas of aerodynamically generated sound and subsonic aerodynamics. In the area of sound the following projects are being conducted:

(a) Correlation of sound with hot wire measurements in a jet. A direct correlation between the turbulence (the cause) and the sound (the effect) is being attempted.

(b) Shielding flap scheme of jet noise suppression. The effectiveness of a wing as a shield for jet noise is being examined experimentally.

(c) Wind noise in vehicles. An experiment is being conducted to determine the relation between the jet flow over a cavity and the noise generated by the flow.

(d) Model of Mach wave noise emanating from the lip of a supersonic jet. A mathematical analysis is being made to delineate the mechanisms of noise generation of a rocket nozzle.

(e) Extended near-field concept for sonic boom alleviation. The possibility of delaying the transition of the near field signature to the far field pressure signature is being examined. In the area of subsonic aerodynamics the lift distribution and moment of wing cutting obliquely through a simulated trailing-vortex of another airplane is being determined.

Department of Defense
Air Force
DYNAMICS OF VORTICES AND SHOCKWAVES IN NONUNIFORM MEDIA
California Institute of Technology
School of Engineering

DF032500
Contract AF-AFOSR-2092-71
Project 9781, Task 02
7/73 to 6/74
Funds $40,900

Aircraft operations in all flight regimes involve vortices in flow field and wakes. The behavior of vortices has profound influence on aerodynamic forces and the trailing vortices are the crucial phenomenon in the notorious aircraft wake turbulence hazard. This effort has made significant progress in theoretical understanding of vortex motion. The current effort will extend this work to consider the influence of various nonlinearities in the equations of motion. Also, water tunnel experiments will be performed in which the detailed structure of trailing vortices behind lifting surfaces will be studied by means of a laser doppler velocimeter. The shockwave aspects of the past research will also be continued with an experimental investigation of focussed shockwave propagation through the focal point. The shockwave effort is relevant to improved understanding of super booms. It is hoped that the experiments will suggest possible simplifications to the analytical models for focussed shockwaves.

Department of Defense
Air Force
THEORETICAL AND EXPERIMENTAL INVESTIGATIONS IN HIGH SPEED AERODYNAMICS
Cornell Univeristy
School of Engineering

DF001060
Contract F44620-69-C-0063
Code AA
7/73 to 6/74
Funds $165,925

Weapons delivery superiority requires continual refinements in aircraft and missiles. More complete knowledge of aerodynamics is critical to such refinements. This is a broad program of research in aerodynamics, with relevance to low speed performance of tactical aircraft, aerodynamic noise and sonic boom minimization, aerodynamic optimization of aircraft, and high altitude hypersonic flight. Problems are being studied in the areas of boundary layer flows, including unsteady boundary layer separation and flows with variable viscosity - gas dynamics, including fluid dynamic processes in gas laser, blast wave experiments, and rarefied hypersonic leading edge flow - aerodynamic noise, including non-uniform cascade theory, non-uniform flow over blunt bodies and propagation of non-linear waves - supersonic drag with emphasis on analytical techniques for positioning of nacelles and stores for an overall optimum area-rule shaping.

Department of Defense	DN223260
Navy	Contract N00014-72-C-0200
TIP VORTEX EFFECTS IN ROTARY-WING AERODYNAMICS	7/72 to 6/73
Sage Action Incorporated	Funds $48,116

To significantly reduce undesirable rotor blade noise signatures, and alleviate the blade-tip vortex interaction problem. The role of the tip vortex in rotary-wing aerodynamics will be investigated and possible means of control of the tip vortex will be examined. If this exploratory effort is successful, an extremely useful technique will be available for solution of severe rotary-wing aerodynamic, structural, and noise problems.

The total flowfield including the tip vortex of a model rotor blade will be investigated by means of an advanced helium bubble flow visualization technique. Techniques to reduce the blade vortex interference effects will be evaluated. The new idea in this research of examining the interference of a tip vortex from a preceeding blade by means of a second blade positioned upstream in a wind tunnel should reveal for the first time the violent changes in angle of attack and stall in the interference region.

Department of Defense	DAOK3720
Army	Contract DAAK02-72-C-0623
GLARE AND NOISE REDUCTION OF HELICOPTER ROTOR BLADES	7/72 to 6/73
McCoy Electronic Corporation	Funds $25,000

To develop various materials and compositions capable of reducing the glint, glare, and noise from helicopter rotor blades without impairing lift or increasing weight or drag.

Task envisions the making of a working model rotor blade upon which an acoustic surface wave will be generated by means of metal electrode transducer excited by the acoustic bulk-waves from piezoelectric vibrators (i.e. quartz crystals). The generated acoustic surface wave will then be propagated along a thin piezoelectric sheet which when lead-phased should regulate the movement of the bound-vortex layer of air increasing the rotor blades lift while simultaneously reducing the glint and glare. In addition, possible method of noise reduction via bow wave extension and creation of a potential gradient across the airfoil will be included in the model, but not be capable of demonstration.

Department of Defense
Army
UNSTEADY AERODYNAMICS OF BLADE-VORTEX INTERACTION 6495-E
Massachusetts Institute of Technology
School of Engineering

DAOB9173
Contract DA-31-124-ARC(D)-471 Code RB
7/73 to 6/74
Funds Unknown

To study the unsteady aerodynamic mechanisms responsible for helicopter noise. Improved understanding of the aerodynamic noise generation of a helicopter could lead to new methods of improving the aerodynamic performance and decreasing the amount of noise generated by helicopters. Both are of vital importance in improving the usefulness of the helicopter for Army missions.

Approach - work will begin with simpler two-dimensional models and will be extended to an exact treatment of the three-dimensional problem in both steady and unsteady flow. The treatment will be concerned primarily with inviscid flow; however, an investigation of the effects of viscosity will be included in determining the vortex curve boundaries. The approach, while numerical in character, may be described as exact in the sense that true boundary locations will be accounted for and the exact solution will be obtained as the computational network is refined.

Department of Defense
Army
INVESTIGATION OF NOISE GENERATION ON A HOVERING ROTOR 8704-RN-8704
Boeing Company

DAOC9091
Contract DAHC04-69-0087
7/72 to 6/73
Funds Unknown

To define the noise field generated by a rotor. Investigation of noise generation of a helicopter rotor is important for the Army's effort to make its helicopters less noisy for more effective field operations. This research is important to the Army in that it represents a long range effort to reduce Army aircraft detection time.

Noise level tests and vortex visualization tests will be made with a set of rotor blades mounted on a whirl tower. Smoke generation in the blade and high speed motion picture photography will be employed for vortex visualization tests. Near and far field acoustical data will be collected. Following data reduction, an analysis will be made of the relative levels and frequency distributions of rotational noise, vortex noise and of any blade slap noise that might occur during tests. The relative positions of smoke will be evaluated at the points where the noise is generated as determined from acoustical measurements.

DOD ROTATING MACHINERY NOISE PROGRAMS

Department of Defense	DF032400
Air Force	Contract F44620-71-C-0104
INSTABILITY AND NOISE GENERATION IN AIR-BREATHING PROPULSION SYSTEMS	7/73 to 6/74
Ultrasystems Incorporated	Funds $37,661

Effective weapon delivery, defense, reconnaissance, and transport vehicles require propulsion systems with stable operating characteristics and minimal noise levels. Results obtained from this research will aid in understanding and controlling combustion instability in air-breathing main and auxilliary combustors, in providing guidelines and techniques for modifying the combustion processes for minimum noise levels, and in establishing criteria for engine design, development, and control. This research encompasses studies of fundamental physical mechanisms driving combustion instability, of mechanisms by which combustion affects the general sound field surrounding an engine, and of coupling between these mechanisms and combustor operating conditions. Included will be studies of the detailed phenomenological processes which determine the nature of the interactions of initially small disturbances and discrete, discernible combustion zones existing in the combustor. Existing contractor chemical and fluid mechanical computer programs will be used in conjunction with data and qualitative observations obtained from laboratory experiments. Particular emphasis will be placed on fundamental fluid mechanics and combustion of vortex stabilized combustors, e.g., V-gutter and dump combustors. A computer model of these processes will be formulated, validated by experiment, and used as the basis for developing a combustor stability prediction program based on combustor geometry and operating conditions. Dominant modes of instability will be predicted and recommendations made concerning effectiveness of stabilizing measures. Mechanisms by which combustion affects the general sound field surrounding an engine will also be investigated and guidelines provided for modifying the combustion processes to obtain minimum noise levels.

Department of Defense	DF034900
Air Force	Contract AF-AFOSR-2365-72
COMBUSTION GENERATED IN TURBO-PROPULSION SYSTEMS	7/72 to 6/73
Georgia Institute of Technology School of Aerospace Engineering	Funds $24,200

For specific missions involving weapon delivery and defense, transport, reconnaissance and rescue, advanced efficient air-breathing and hybrid engines are required with minimal noise emission levels to deter detection and avoid aircraft component damage and reduced efficiency of and hazard to ground and flight personnel. Also to maintain environmental pollution within tolerable limits it is mandatory that aircraft noise emissions be minimized. This research on fundamental physical mechanisms and processes involved in combustion noise production and transmission in primary and augmentor air-breathing combustors will aid in providing guidelines and techniques for modifying the combustion process for minimal noise output and development of effective combustor noise suppressing devices for these advanced engines. This program encompasses theoretical and experimental studies directed toward isolating the origins and transmission of combustion noise in turbo-propulsion combustors. Included will be studies of various aspects of free flame, flameholder flame, and primary combustor can combustion noise. Sound power output, spectral content and directionality characteristics will be determined. Scaling rules will be generated and compared with various theoretical approaches to the problem. Diagnostic emission measurements will be made to isolate the origin of combustion noise. Theoretical acoustics will be used to solve the problems of sound radiation from afterburner and primary combustors to the surrounding atmosphere.

NOISE GENERATION BY A TRANSONIC COMPRESSOR ROW — Project 9781, Task 02, Work Unit 003
Cornell Aeronautical Laboratory Inc.

The Air Force is presently and will continue to be in the foreseeable future a large user of high subsonic jet aircraft. The principal means of propulsion of such aircraft is the high bypass-ratio turbofan engine. An undesirable byproduct of these engines is the generation of noise which causes such adverse effects as degradation in human performance, reduced reliability of structural and equipment subsystems, and increased maintenance cost. The design of vehicle parts and soundproofing which alleviate these effects requires accurate definition of the intensity and occurrence of the noise. In order to partially fulfill this requirement a theoretical study of the problem of fan-noise generation in a high bypass-ratio turbofan engine is being made. The main emphasis in this study is the noise aspect of the three-dimensional, transonic flow through a single blade row. A linear acoustic theory for the case of non-lifting blades is being applied to the problem of noise generation. An effort is being made to extend the theory to lifting blades and to examine the effect of more realistic duct geometries.

HIGH INTENSITY SOUND
University of Texas

Project 9781, Task 02,
Work Unit 002

This research is concerned with investigating the behavior of high-intensity sound and applying the understanding gained to problems of interest to technology such as sonic boom, propagation of intense noise from jet engine compressors, underwater propagation, etc. This is a theoretical and experimental effort on high-intensity sound and its interaction with a real media. The purpose of the work is to study the phenomena that distinguish nonlinear acoustics from linear acoustics and to apply the knowledge gained to physical problems. Specific topics being studied are:

(a) Stability of the acoustic boundary layer. The object is to predict the threshold at which a transition from laminar to turbulent flow takes place. The frequency dependence of this threshold is of particular interest.

(b) Standing waves of finite amplitude. Chester's theoretical predictions are being checked by experiments.

(c) Quasi-plane-wave mode for finite-amplitude waves in a tube. Experimental tests are being conducted to check past theoretical solutions.

(d) Finite-amplitude waves in relaxing media.

(e) Electrical transmission-line analogs of acoustical propagation problems, such as progressive waves in relaxing media, random in homogeneous, turbulent media, or nonlinear media.

SMALL TURBINE ENGINE NOISE REDUCTION
Garrett Corporation

Project 3066, Task 14,
Work Unit 001

The purpose of this program is to develop the technology base necessary to effectively reduce the noise signature of existing small turboprop and turbofan engines. Although the program is primarily aimed at light aircraft propulsion, the technology generated is directly applicable to auxilliary power unit silencing. The specific technical objectives of the effort are to accurately predict the radiated acoustic signature and aural detectability of existing turboprop and turbofan propulsion systems in the 80 to 1000 shaft horsepower class for turboprops and the 400 to 5000 pound thrust class for turbofans, to develop effective methods to minimize propulsion system aural detectability, and to determine the engine performance and weight penalties associated with the various suppression methods.

ROTATING MACHINERY NOISE GENERATION

Project 3066, Task 03,
Work Unit 34

The overall objective of this program is to develop an improved understanding of noise in axial flow compressors so that design rules may be formulated for reduced noise. The specific technical objectives of the effort are:

(a) To develop a direct lifting surface theory for compressible, linearized flow through a rotating blade row.

(b) To develop approximate models for noise generation by rotor-stator interaction.

(c) To correlate results of lifting surface theory with experiment.

(d) To analyze dominant nonlinear effects in the inviscid, three-dimensional flow through a rotating blade row.

Department of Defense	DN123475
Navy	Contract N00014-67-0151-0029 Subgroup
Office of Naval Research 473	
AIRCRAFT COMBUSTION GENERATED NOISE	7/73 to Cont
Princeton University	Funds $64,022
Aerospace, Mech. Sci. Dept.	

Within the Navy aircraft, missile and space power and propulsion program, this effort offers the possibility of alleviating jet engine noise by research on nonsteady combustion and gas dynamics phenomena. This research makes use of past efforts on nonsteady combustion coupled with nonsteady gas dynamics as applied to aircraft combustor and afterburner generated noise with emphasis on causes of suppression of such noise. The study seeks quantitative descriptions of the driving mechanisms as well as methods of predicting and minimizing such noise.

Special instrumentation will be utilized in conjunction with an anechoic chamber and a combustion rig to conduct diagnostic measurements designed to elucidate sources of sound in a combustor-jet combination, to measure effects of controlled changes and to observe relationships between flow pattern and noise characteristics. Concurrent theoretical report will involve modeling and treat noise generation from turbulent mixing regions, interactions of such turbulent flow with shock waves and unsteady rough burning processes. Information will be compared with typical jet engine firing tests involving various operating parameters.

Department of Defense
Army
INVESTIGATION OF GEARBOX DESIGN MODIFICATION FOR REDUCING NOISE, ARMY AIRCRAFT TRANSMISSION SYSTEMS
Mechanical Technology Inc.

DAOC4046
Contract DAAJ02-72-0040
7/73 to 6/74
Funds $26,456

The objective of this program is to identify practical gearbox design modifications which will help alleviate the gearbox noise problem in the CH-47 transmission. In addition, analytical methods for predicting and reducing gearbox noise sidebands will be developed to permit design analysis of this significant noise source.

Select component modifications, based on Contract DAAJ02-70-C-0035, to be investigated for noise attenuation in the CH-47 helicopter transmission. Perform vibration calculations so that candidate configuration is optimized from the standpoint of noise and vibration reduction. Identify modifications having greatest noise reduction potential. Utilizing test results obtained under Contract DAAJ02-71-C-0020. Determine the mechanamisms producing planet-pass sidebands and then modify existing computer programs accordingly to develop analytical methods to reduce sideband amplitudes.

COMPUTERIZED PROCEDURE TO ASSESS TURBINE ENGINE PERFORMANCE/NOISE TRADES

Project 3066, Task 14,
Work Unit 06

The objective of this program is to develop an effective design procedure relating aircraft engine performance and noise. The specific technical objectives of this program are: (a) to develop effective uninstalled engine noise prediction methods applicable to current and future gas turbine engines, (b) to develop techniques for the prediction on installed engine noise levels including the effects of special noise reduction devices, and (c) to develop methods to assess propulsion performance and weight penalties as a function of noise level reduction.

DOD DUCT ACOUSTICS AND SUPRESSION PROGRAMS

SOUND TRANSMISSION THROUGH DUCTS

Project 3066, Task 14,
Work Unit 09 (AF)

The purpose of this effort is to develop a numerical procedure to predict the effects of engine ducting on sound propagation. The specific technical objectives of the effort are to review existing theoretical and empirical methods for the prediction of sound propagation through and radiation from ducts and to develop a unified general theory based on this review. This prediction theory will then be incorporated into a general computerized procedure to assess turbine engine noise/performance trades.

Department of Defense
Army
DEVELOPMENT OF NOISE
ATTENUATING SUBSTANCE
Lehigh University

DAOC4924
Contract DAAD05-72-C-0175
7/73 to 6/74
Funds $19,950

To develop a paint-like substance which will damp thin panel vibration.

A Latex substance consisting of two layers - a viscoelastic latex IPN undercoating having damping capabilities at the temperature and frequency range of interest and a reinforced plastic constraining layer which has a high modulus. Steel tests panels will be coated, evaluated, and compared to commercial materials at frequent intervals. The best paint will be recommended for Army use on material where personnel are exposed.

DOD STRUCTURAL RESPONSE AND INTERIOR NOISE PROGRAMS

Department of Defense
Army
STRUCTURAL MATERIALS WITH DAMPING
CHARACTERISTICS FOR APPLICATION TO
HELICOPTERS
U.S. Army

DAOD4751
7/72 to 6/73
Funds Unknown

The objective is to produce a material that can be used to dampen noise in helicopters (engine mounts, driveshafts, honeycomb linings).

Titanium-nickel alloys in the 50-50 range will be fabricated and tested to determine their yield strength and damping capacity. Acoustical attenuation as a function of frequency (0-20 percent) and temperature (-60 degrees centigrade to 100 degrees centigrade) will be measured and by alloying or heat treatment the yield strength and damping characteristics will be optimized. X-ray studies will be made to correlate the lattice arrangement with the damping characteristics and yield strength.

DOD FLIGHT AND INSTALLATION EFFECTS PROGRAMS

Department of Defense	DAOD8982
Army	Contract DAHC04-72-C-0040
ANALYTICAL STUDIES OF HELICOPTER ROTOR BROADBAND NOISE GENERATION	7/73 to 6/74
10299-E	Funds $33,861
Sikorsky Aircraft	

An analytical study will be made to establish a closed form solution for predicting the broadband noise intensity radiated by helicopter rotors. This research should develop techniques which will reduce the aerodynamically generated noise made by helicopters.

Experimental studies will be made of isolated airfoils in an existing acoustic-wind tunnel. The data obtained and other existing data will be statistically analyzed to provide an empirical equation which will then serve as a measure by which the validity of the theoretical equation will be examined.

Department of Defense	DAOD9005
Army	Contract DA-ARO(D)-31-124-71-G-17
STUDIES IN LOW SPEED FLIGHT 10233-E	7/72 to 6/73
Georgia Institute of Technology	Funds $120,000
School of Aerospace Engineering	

Investigation of problems associated with low speed flight of helicopters, such as the hovering rotors, vortex wake, blade slap noise, rotor flutter, and the instability of tensioned sheets with cutouts. The Army helicopter program has a definite need to improve the capability of its helicopters to hover near the ground so as to take off and land precisely at a surface location with maximum payload. The present vortex wake and rotor flutter of the vehicle interferes with ground personnel as well as reduces the payload capability of the vehicle. Blade slap noise alerts the enemy to the helicopter's presence and must be reduced significantly to improve the element of tactical suprise.

(a) Develop a method for calculating vortex wakes in the hovering performance of multi-bladed helicopter rotors, (b) the interaction of the helicopter blade with the vortex field shed from the preceding blades as a cause of blade slap, (d) the structural dynamic characteristics of the rotor-blade system that gives rise to flutter due to the unsteady air loads on the blade, (C) the instability of thin sheets with cutouts and cracks.

Department of Defense Army SYSTEMS STUDY OF HELICOPTER NOISE REQUIREMENTS 8713-E Massachusetts Institute of Technology School of Engineering	Contract DAHC04-69-C-0086 7/72 to 6/73 Funds $73,864

To establish a new methodology for systems analysis which includes noise criteria and to develop a new wind tunnel facility for making useful noise measurements on V/STOL aircraft types. It is important for the Army to reduce the noise levels of its helicopters so that the missions of surveillance, reconnaissance and target acquisition can be performed better without giving too much warning of approach to the enemy. The mission accomplishment may still be performed better if just the right combination of noise reduction and performance of the helicopter existed. The question that remains unanswered is - What is the most desirable combination of these parameters so the mission effectiveness will be maximized. This project is aimed towards answering this question.

The initial system studies will be performed, assessing the effect of noise criteria on mission performance. Experimental data on the noise radiated by helicopter rotors in high forward speed flight will be obtained. Emphasis will be in determining the effect of helicopter operating conditions upon the directivity, frequency content and time signature of the noise.

DOD SOUND PROPAGATION PROGRAMS

NOISE FROM LINEAR ARRAY OF LARGE TURBOJET ENGINES AFFDL (In-House)	Project 1471, Task 02, Work Unit 011

The purpose of this program is to determine the interaction effects of multiple turbojet exhaust noise sources in determining the near-field acoustic environment. Data were obtained in the form of sound pressure levels and frequency spectra at various microphone locations. Analog data were recorded on tape for later analysis.

RADIATED NOISE FROM SAILPLANES
AFFDL (In-House)

Project 1471, Task 02,
Work Unit 013

The objective of this effort is to identify the noise associated with a powerless aircraft and to relate this noise to area and velocity parameters of the aircraft. The flyby noise from three sailplanes, Schweizer 2-32, Schweizer 2-33, and Libelle, has been recorded on tape and one-third octave and overall bandwidth analyses obtained. The noise levels from each of the sailplanes follows a sixth power of the velocity and appear to be directly proportional to the turbulent area on the wing. A test report has been prepared which presents the results obtained to date.

Department of Defense
Army
RESEARCH ON HELICOPTER
NOISE 9372-E
Cornell University
School of Engineering

DAOC9164
Contract DAHC04-74-C-0001
7/73 to 6/74
Funds $30,615

To discover, refine and exploit techniques for the analysis and predictions of aerodynamic noise, in particular the noise produced by helicopters and similar-AIRCRAFT, for the purpose of finding techniques for reduction of such noise. The successful field operation of Army helicopters is jeopardized by the noise environment in three ways. Helicopter noise increases the vulnerability of both the machine and crew to ground fire, distracts the crew in the performing of their duties, and induces sonic fatigue in construction elements. Thus, this investigation has a high degree of relevance to effective utilization of rotorcraft since it will identify noise sources and describe noise propagation relative to helicopters.

DOD PROPELLER NOISE PROGRAMS

PROPELLER TECHNOLOGY

Project 3066, Task 12

Significant propeller system technology advancement is an area of major importance for V/STOL and light aircraft. The propeller technology task consists of three areas:

(a) lighweight propeller and propeller/gearbox development;

(b) improvement of propeller aerodynamic performance and analytical prediction techniques;

(c) prediction and reduction of propeller and gearbox system noise.

More specifically, near term areas of concern are: decreasing propeller/gearbox system weight through the use of high strength-to-weight ratio materials and composites; improving propeller system performance through the application of cyclic pitch and variable geometry; improving basic airfoil design for optimum performance; determining accurate static thrust prediction methods; improving noise prediction techniques through improved basic noise source theory; and improving propeller noise scaling techniques and noise reduction through utilization of unique propeller designs based on noise source theory information.

PROPELLER ACOUSTICS RESEARCH

Project 3066, Task 12,
Work Unit 07

The overall objective of this program is to experimentally determine the noise generation mechanisms for low tip speed propeller airfoils. The specific technical objectives of the effort are: (a) to determine the relative effects of upstream turbulence, boundary layer fluctuations and vortex shedding on radiated noise, and (b) to experimentally verify the theoretical prediction models developed under contract F33615-70-C-1135 and presented in AFAPL-TR-71-55 entitled "Propeller Noise at Low Tip Speeds."

QUIET PROPELLER CONCEPT EVALUATION

Project 3066, Task 12,
Work Unit 08

The objective of this program is to evaluate the noise characteristics of various tail rotor configurations to determine the noise reduction potential of various new designs. Variables to be investigated include number of blades, blade to hub phasing angles and blade length.

LOW NOISE PROPELLER TECHNOLOGY DEMONSTRATION

Project 3066, Task 12,
Work Unit 12

The objective of this exploratory research program is to develop a reliable design procedure for quiet propellers applicable to reconnaissance/surveillance aircraft. The specific technical objectives of this effort are: (a) to modify existing Air Force propeller noise prediction computer programs to account for forward flight effects, and (b) to produce a series of design charts that will be useful in design of future propeller driven quiet aircraft.

IV. NSF PROGRAMS

Note that these are not discussed in the main text.

National Science Foundation
Div. of Engineering
AN INVESTIGATION OF ACOUSTIC FEEDBACK FOR THE REDUCTION OF JET NOISE
University of Michigan
School of Engineering

GK-33801
4/72 to 4/73
Funds $60,000

This project will investigate the part acoustic feedback (resonance) plays in the generation of noise from supersonic jets with special consideration given to the possibility of shifting the frequency of a significant part of the radiated acoustic energy outside the range of the human ear.

Phase relationships between movements of shock waves and disturbance created will be determined using ultra-high-speed Schilieren or shadow photographs. Local flow properties will be measured and the sound reflecting and absorbing surfaces in various geometries will be examined.

National Science Foundation
Div. of Engineering
RESEARCH INITIATION-APPLICATION OF UNSTEADY AIRFOIL THEORY
Widener College
Graduate School

GK-37433
3/73 to 8/74
Funds $17,000

This research project will investigate the pressure fluctuations on blade surfaces of a single stage compressor. In particular it will be clarified whether the chopping effect of blades moving at high speeds relative to one another without the presence of low momentum flow is the predominant source of noise or the mere interference of blades with flow perturbations.

Experimental tests will be aimed to separate the sources of pressure fluctuations. Using high response pressure transducers a quantitative answer of the magnitude of these fluctuations is to be obtained. An integration of these results over the blade surface will give answers as to the magnitude of the experienced lift fluctuations which will then be compared with existing theories.

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National Science Foundation
Div. of Engineering
COMPRESSOR NOISE REDUCTION
WITH A SONIC INLET
South Dakota State University
School of Arts

GK-5030 A#1
10/71 to 10/72
Funds $19,350

The purpose of this investigation is to develop some fundamental understanding of the aerodynamic-problems associated with the sonic inlet. Specific emphasis will be given the following: (a) A theoretical and experimental verification of a method for optimizing the design of center body. (b) Experimental investigation of the effects of splitters and vortex generators on secondary air injections. (c) Verification of the theoretical studies on shock stability.

National Science Foundation
Div. of Engineering
COMBUSTION GENERATED NOISE
Georgia Inst. of Technology
School of Aerospace Engineering

GK-32544
2/72 to 2/73
Funds $13,950

A combined experimental-theoretical program will be undertaken to isolate the origin of combustion generated noise and to discover appropriate scaling rules associated with this noise. Primary attention is to be focused on premixed turbulent flames, although several aspects of diffusion flame noise will also be investigated.

An extension of the principal investigator's original theory of combustion generated noise will be attempted to include the effects of approach flow turbulence level, directional radiation as caused by refraction and dipole source effects, and the effects of diffusion flames. Information gained from this analysis will be used to direct experiments on free flames. An analysis will also be initiated to determine the effects of reflecting surfaces on the combustion noise source behavior. Suggestions for appropriate experimental variables will be made to extract the effects of reflecting surfaces.

The data obtained on free flames will be analyzed and compared with the theory. Correlations will be obtained for sound power output, directionality, and spectral content. Furthermore, the relation between the reaction rate fluctuations and the sound power output will be determined. An analysis will be completed for the radiation of noise from a flame-containing enclosure to the surroundings. The modification to sound power output, spectral content and directionality will be determined as compared with free flame generated noise.

National Science Foundation
Division of Engineering
RANDOM VIBRATIONS OF ALMOST
PERIODIC STRUCTURES
University of Illinois
School of Engineering

GK-34136X
5/72 to 3/73
Funds $44,900

The first part of this research will consider the random variation of periodic units from the designed (or norm) configuration. One objective will be to determine the probability distribution of each natural frequency and the corresponding normal mode of the structure from the probability distribution of the varied geometrical and material parameters. The investigation will then be extended to the response of such a structure to random forcing fields. The convected frozen noise field and convected but slowly changing noise field which have been used as mathematical models for boundary layer turbulence will be included among several other types of random excitation.

National Science Foundation
Division of Engineering
RANDOM VIBRATIONS OF ALMOST
PERIODIC STRUCTURES
University of Illinois
School of Engineering

GK-34126 X1
4/73 to 3/74
Funds $44,100

The first part of this research will consider the random variation of periodic units from the designed (or norm) configuration. One objective will be to determine the probability distribution of each natural frequency and corresponding normal mode of the structure from the probability distribution of the varied geometrical and material parameters. The investigation will then be extended to the response of such a structure to random forcing fields. The convected frozen noise field and convected but slowly changing noise field which have been used as mathematical models for boundary layer turbulence will be included among several other types of random excitation.

This action provides a second year of support for a continuing grant.

National Science Foundation
Div. of Engineering
ENLARGEMENT OF ANECHOIC CHAMBER FOR NOISE RESEARCH
Syracuse University
Graduate School

GK-32585
2/72 to 2/73
Funds $24,800

An existing anechoic chamber facility (wedge-tip to wedge-tip size 12' x 10' x 9') will be enlarged to 20 feet by 15 feet by 11 feet wedge-tip to wedge-tip. The enlarged anechoic chamber facility will serve as a more reliable tool for the noise research listed below, both because of its greater capacity and lower effective cut-off frequency characteristics.

(a) Noise experiments in a hard room.

(b) Compressor and turbine noise.

(c) Traffic noise control.

(d) Effect of impulsive noise on the auditory system.

National Science Foundation
Div. of Engineering
PREDICITION AND MEASUREMENT OF SOUND PROPAGATION IN LINED FLOW DUCTS
University of Minnesota

Proposal P2K0644
FY 72 - 12 months
Funds $37,800

The theoretical portion of this project will include the analysis of two-dimensional steady flow in a porous wall duct and to initiate a study of acoustic wave propagation in the same porous duct. The experimental portion will include the development of and the measurement of pressure spectrum in the porous wall ducts.